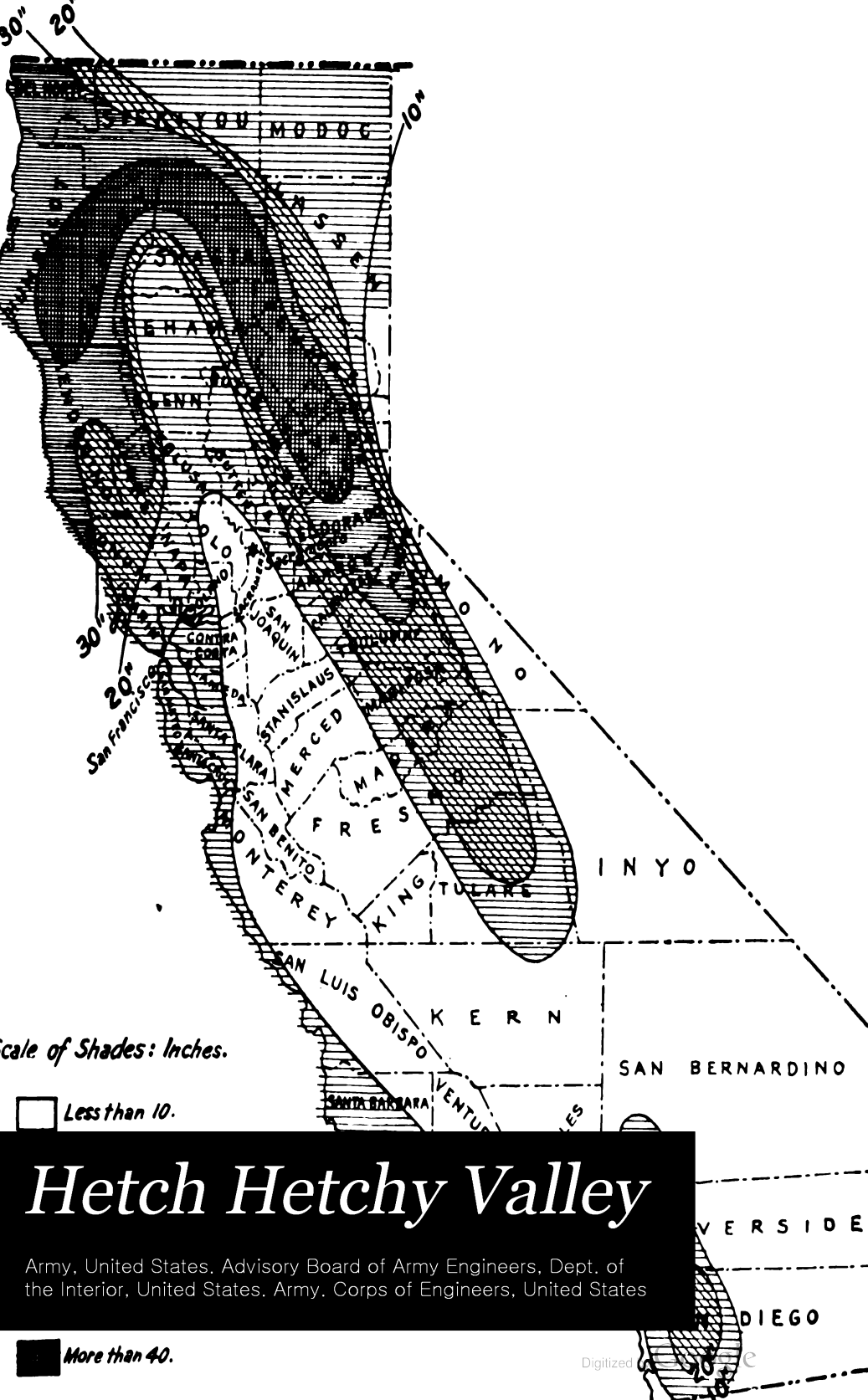
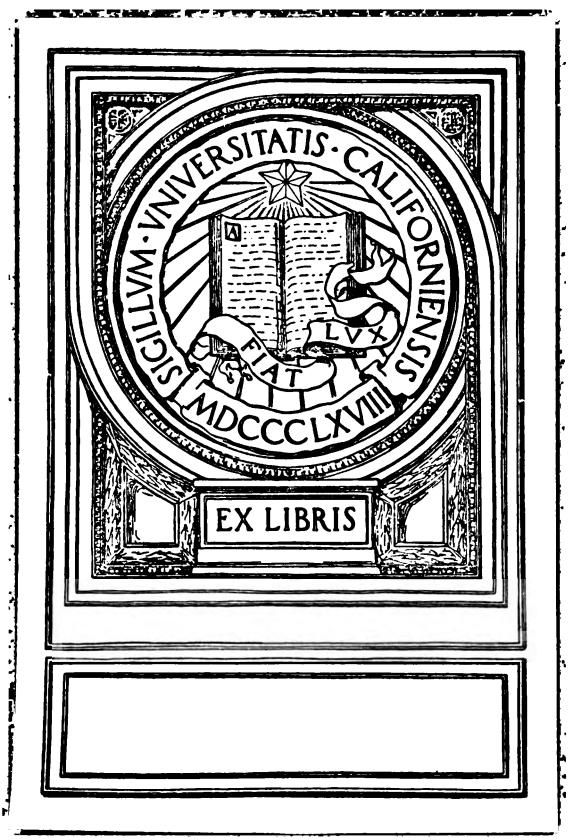


Hetch Hetchy Valley

Army, United States. Advisory Board of Army Engineers, Dept. of the Interior, United States. Army. Corps of Engineers, United States



U. S. Engineer Dept.

HETCH HETCHY VALLEY

REPORT

OF

ADVISORY BOARD OF ARMY ENGINEERS

TO THE

SECRETARY OF THE INTERIOR

ON

INVESTIGATIONS RELATIVE TO SOURCES OF WATER SUPPLY FOR SAN FRANCISCO AND BAY COMMUNITIES

FEBRUARY 19, 1913

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

CONTENTS.

ILLUSTRATIONS.

ABBREVIATIONS

A. F.	Acre-feet.
Sec.-ft.	Cubic feet per second.
M. G.	Million gallons.
M. G. D.	Million gallons daily.
H. P.	Horsepower.

EQUIVALENTS.

1 second-foot=646,000 gallons daily=40 miner's inches.
1 second-foot for 1 day=1.98 acre-feet.
1 acre-foot=43,560 cubic feet=326,000 gallons.
1 M. G.=3.065 acre feet=133,900 cubic feet.
1 M. G. D.=1.55 second-feet=1,119 acre-feet per year.
1 M. G. D. lifted 1 foot requires 0.176 horsepower at 100 per cent efficiency.

HETCH HETCHY VALLEY.—REPORT OF ADVISORY BOARD OF ARMY ENGINEERS TO THE SECRETARY OF THE INTERIOR ON INVESTIGATIONS RELATIVE TO SOURCES OF WATER SUPPLY FOR SAN FRANCISCO AND BAY COMMUNITIES, FEBRUARY 19, 1913.

ERRATA.

Page 35, line 9. *For* "3 per cent" *read* "39 per cent."

Page 46, line 12. *For* "divisions" *read* "decisions."

Page 64, line 1. *For* "These scales are" *read* "Before reduction for publication these scales were."

Page 72, table showing precipitation. In second column the figures for San Francisco for 1850–51 should be bracketed, thus [7.42]; in third column the figures for Sacramento for 1850–51 should be bracketed, thus [4.71]; in the third column, headed Sacramento, the long bracket at right extending from 11.57 to 8.47, inclusive, should be broken into two, one including 11.57 and 7.87, the other including 16.64 to 8.47; the bracket at the right should be omitted for the following: Sacramento, 1886–87, 1887–88, 1888–89; San Francisco, 1897–98, 1898–99, 1899–1900; Auburn, 1886–87, 1887–88, 1888–89; Georgetown, 1886–87, 1887–88, 1888–89; Placerville, 1897–98, 1898–99, 1899–1900; La Grange, 1876–77, 1877–78, 1878–79; La Grange, 1886–87, 1887–88; Modesto, 1886–87, 1887–88, 1888–89; Merced, 1876–77, 1877–78, 1878–79; Merced, 1886–87, 1887–88, 1888–89.

Page 78, table. Insert the word "annually" in each column under word "Conserved."

Page 80, line 23. *For* "$(y=4.8\times0.7)$" *read* "$(y=4.8x^{0.7})$".

Page 81, legend and note on diagram. *For* "S. F. B." *read* "S. B. F."

Page 89, line 7. *For* "necleus" *read* "nucleus."

Page 93, line 29. Insert a comma after the word "proponents."

Page 95, table. Take out word "acre-feet" after heading "Capacity"; insert word "Acre-feet" at head of fourth and fifth columns.

Page 100, last line. *For* "(see text, p. 100)" *read* "(see text, p. 99)."

Page 119, line 21. *For* "as per statement on the diagram" *read* "as per statement under the diagram and on page 121."

Page 125, table at bottom of page. The first line of figures in table should be separated from the second line by a rule.

Page 131, note below center of page. After word "say" take out comma and word "of"; insert comma after word "half."

Page 135, footnotes 1 and 2. *For* "Minus" *read* "Equals."

Page 142, line 14. Insert "of" after "loss."

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REPORT OF ADVISORY BOARD OF ARMY ENGINEERS ON THE INVESTIGATIONS RELATIVE TO WATER SUPPLIES FOR SAN FRANCISCO AND BAY COMMUNITIES.

WASHINGTON, D. C., *February 19, 1913.*

Hon. WALTER L. FISHER,
Secretary of the Interior.

SIR: The board of officers of the Corps of Engineers, United States Army, appointed by Special Orders, No. 116, War Department, May 18, 1910, for the purpose of acting in an advisory capacity to the Secretary of the Interior on the question of the use of the Hetch Hetchy Valley for a storage reservoir as a part of the water supply of San Francisco, has the honor to submit the following report:

GARFIELD PERMIT.

On May 11, 1908, the Secretary of the Interior, the Hon. James R. Garfield, authorized the city of San Francisco to use the Hetch Hetchy Valley of the Tuolumne River as a reservoir site in connection with other works on branches of this river. This permit appears in a letter of the above date, from the Secretary to the Commissioner of the General Land Office—the complete letter being printed in the "Proceedings before the Secretary of the Interior in re use of Hetch Hetchy reservoir site in the Yosemite National Park by the city of San Francisco," 1910.

The terms of the permit are as follows:

1. The city of San Francisco practically owns all the patented land in the floor of the Hetch Hetchy reservoir site and sufficient adjacent areas in the Yosemite National Park and the Sierra National Forest to equal the remainder of that reservoir area. The city will surrender to the United States equivalent areas outside of the reservoir sites and within the national park and adjacent reserves in exchange for the remaining land in the reservoir sites, for which authority from Congress will be obtained if necessary.

2. The city and county of San Francisco distinctly understands and agrees that all the rules and regulations for the government of the park, now or hereafter in force, shall be applicable to its holdings within the park, and that, except to the extent that the necessary use of its holding for the exclusive purpose of storing and protecting water for the uses herein specified will be interfered with, the public may have the full enjoyment thereof, under regulations fixed by the Secretary of the Interior.

3. The city and county of San Francisco will develop the Lake Eleanor site to its full capacity before beginning the development of the Hetch Hetchy site, and the development of the latter will be begun only when the needs of the city and county of San Francisco, and adjacent cities which may join with it in obtaining a common water supply, may require such further development. As the drainage area tributary to Lake Eleanor will not yield, under the conditions herein imposed, sufficient run-off in dry years to replenish the reservoir, a diverting dam and canal from Cherry Creek to Lake Eleanor Reservoir for the conduct of waste flood or extra seasonal waters to said reservoir is essential for the development of the site to its full capacity and will be constructed if permission is given by the Secretary of the Interior.

4. The city and county of San Francisco, and any other city or cities which may with the approval of the municipal authorities, join with said city and county of San Francisco in obtaining a common water supply, will not interfere in the slightest particular with the right of the Modesto irrigation district and the Turlock irrigation district to use the natural flow of the Tuolumne River and its branches to the full extent of their claims, as follows: Turlock irrigation district, 1,500 second-feet; Modesto irrigation district, 850 second-feet; these districts having, respectively, appropriated the foregoing amounts of water under the laws of the State of California.

To the end that these rights may be fully protected, San Francisco will stipulate not to store, nor cause to be stored, divert, nor cause to be diverted from the Tuolumne River or any of its branches any of the natural flow of said river when desired for use by said districts for any beneficial purposes, unless this natural flow of the river and tributaries above La Grange Dam be in excess of the actual capacities of the canals of said districts, even when they shall have been brought up to the full volumes named, 1,500 second-feet for the Turlock irrigation district and 850 second-feet for the Modesto irrigation district.

5. The city and county of San Francisco will in no way interfere with the storage of flood waters in sites other than Hetch Hetchy and Lake Eleanor by the Modesto and Turlock irrigation districts, or either of said districts, for use in said districts, and will return to the Tuolumne River above La Grange Dam, for the use of said irrigation districts, all surplus or waste flow of the river which may be used for power.

6. The city of San Francisco will, upon request, sell to said Modesto and Turlock irrigation districts, for the use of any land owner or owners therein, for pumping subsurface water for drainage or irrigation, any excess of electric power which may be generated, such as may not be used for the water supply herein provided and for the actual municipal purposes of the city and county of San Francisco (which purposes shall not include sale to private persons nor to corporations), at such price as will actually reimburse the said city and county for developing and transmitting the surplus electrical energy thus sold, the price, in case of dispute, to be fixed by the Secretary of the Interior; and no power plant shall be interposed on the line of flow except by the said city and county, except for the purposes and under the limitations above set forth.

7. The city and county of San Francisco will agree that the Secretary of the Interior shall, at his discretion or when called upon by either the city or the districts to do so, direct the apportionment and measurement of the water in accordance with the terms of the preceding clauses of this stipulation.

8. The city and county of San Francisco, when it begins the development of the Hetch Hetchy site, will undertake and vigorously prosecute to completion a dam at least 150 feet high, with a foundation capable of supporting the dam when built to its greatest economic and safe height, and whenever, in the opinion of the engineer in charge of the reservoirs on behalf of said city and county and of the municipalities sharing in this supply, the volume of water on storage in the reservoirs herein applied for is in excess of the seasonal requirements of said municipalities, and that it is safe to do so, that such excess will be liberated at such times and in such amounts as said districts may designate, at a price to said districts not to exceed the proportionate cost of storage and sinking fund chargeable to the volumes thus liberated, the price, in case of dispute, to be fixed by the Secretary of the Interior; provided that no prescriptive or other right shall ever inure or attach to said districts by user or otherwise to the water thus liberated.

9. The city and county of San Francisco will, within two years after the grant by the Secretary of the Interior of the rights hereby applied for, submit the question of said water supply to the vote of its citizens as required by its charter, and within three years thereafter, if such vote be affirmative, will commence the actual construction of the Lake Eleanor Dam and will carry the same to completion with all reasonable diligence, so that said reservoir may be completed within five years after the commencement thereof, unless such times hereinbefore specified shall be extended by the Secretary of the Interior for cause shown by the city, or the construction delayed by litigation; and unless the construction of said reservoir is authorized by a vote of the said city and county and said work is commenced, carried on, and completed within the times herein specified, all rights granted hereunder shall revert to the Government.

On February 25, 1910, the Secretary of the Interior, the Hon. R. A. Ballinger, called upon the mayor and supervisors of San Francisco to show cause why the Hetch Hetchy Valley and reservoir site should not be eliminated from the above permit.

On May 12, 1910, the Secretary of the Interior requested the Secretary of War to appoint a board of Army engineers to act as an advisory board on the question. The board was appointed May 18, 1910. The first hearings were held before the Secretary on May 25 and are printed, as stated above.

As a result of this hearing, the board made a preliminary report to the Secretary of the Interior May 26, 1910, and on May 27 the Secretary sent the following instructions to the city and county of San Francisco:

In the matter of the order directed by the Secretary of the Interior to the mayor and supervisors of the city and county of San Francisco, State of California, on February 25, 1910, to show cause why the Hetch Hetchy Valley and reservoir site should not be eliminated from the permit to said city of date May 11, 1908.

The above-entitled matter having come on regularly to be heard on the 25th day of May, 1910, at the hour of 10 o'clock a. m., and said city and county of San Francisco having, through its representatives, applied for a continuance of said hearing and for further time within which to more fully respond to said order, said application being made upon the ground that sufficient data was not available upon which to make showing responsive to said order, and an adjournment to Thursday morning, May 26, at 10 o'clock a. m., having been taken to permit the advisory board of Army engineers to confer with the engineers representing the several parties interested herein respecting said application and the propriety of granting the same, whereupon the matter of said application for continuance and postponement having been duly and fully considered by the Secretary of the Interior and said advisory board of Army engineers, said board having recommended the same in writing:

It is hereby ordered that said city and county of San Francisco be, and it is hereby, granted to and including the 1st day of June, 1911, within which to respond to said order to show cause, and that hearing upon said order be, and it is hereby, continued until the hour of 10 o'clock a. m. on said last-mentioned date.

Said continuance and postponement is granted for the purpose of enabling said city and county of San Francisco to furnish necessary data and information to enable the Department of the Interior to determine whether or not the Lake Eleanor basin and the watershed contributary, or which may be made contributary, thereto, together with all other sources of water supply available to said city, will be adequate for all present and reasonably prospective needs of said city of San Francisco and adjacent bay cities without the inclusion of the Hetch Hetchy Valley as a part of said sources of supply, and whether it is necessary to include said Hetch Hetchy Valley as a source of municipal water supply for said city and county of San Francisco and bay cities.

In granting said postponement and continuance it is understood said city and county of San Francisco will at once proceed, at its own expense and with due diligence, to secure and furnish to said advisory board of Army engineers all necessary data upon which to make the determination aforesaid, and pending the hearing upon said order to show cause no attempt shall be made by said city or any of its officers or agents to acquire, as against the United States, any other or different rights to the Hetch Hetchy Valley than it now has under said permit, and that no effort shall be made by said city to develop said Hetch Hetchy Valley site.

Said advisory board of Army engineers is hereby authorized to procure such independent data and information as it may deem necessary or proper to a full and complete determination of the matters committed to said board and the Secretary of the Interior for determination, and that said board may call upon the Geological Survey or other bureaus of the Department of the Interior for such assistance as any such bureau may be able to render in the premises.

It is further understood that said city will, as soon as practicable, submit to said advisory board a full exhibition of its proposed plan of development and utilization of water under said permit, together with estimates of the cost thereof, and also a full statement of all outstanding water rights, both for irrigation, power, and other uses on the Tuolumne River and Lake Eleanor basins, and the proposed method of providing for the protection thereof.

All questions as to the validity and legality of said permit of date May 11, 1908, are hereby expressly reserved for decision and determination until said final hearing.

Dated this 27th day of May, 1910.

R. A. BALLINGER,
Secretary of the Interior.

The board on May 27 recommended an appropriation of $12,000 to enable it to carry out the above instructions, which appropriation was made by Congress.

On account of the stated inability of the city to procure within the time allotted the data deemed necessary by the board, postponement was granted from time to time by the Hon. Walter L. Fisher, Secretary of the Interior, until in letter of May 28, 1912, the date of August 1, 1912, was set as the final date for submission of all matter, some of the reports being called for on July 1 and on July 15. The final documents were not, however, submitted by the city until about September 1. Objectors were given until November 1 to reply to the objections. A final hearing before the Secretary was held November 25 to 30, 1912, at which the board was present. The documents submitted by the city are as follows:

LIST OF DOCUMENTS RECEIVED.

Report on the Sacramento River filtration project, by Allen Hazen, consulting engineer. This includes a report on the quality of the water of the Tuolumne River.

Report on the Modesto and Turlock irrigation districts, by J. H. Dockweiler, consulting engineer. Statements on the same matter by John R. Freeman and George T. Prince, consulting engineers, are included in this report.

Report on the McCloud River as a source of supply, and papers relating thereto by Marsden Manson, city engineer, C. E. Grunsky, and John R. Freeman, consulting engineers, and Percy V. Long, city attorney.

Report on the proposed use of a portion of the Hetch Hetchy Valley, Eleanor and Cherry Valleys, as reservoirs, and appurtenant works for the water supply of San Francisco and neighboring cities, by John R. Freeman, consulting engineer.

Report on the sources of water supply, east region of San Francisco Bay, by J. H. Dockweiler, consulting engineer.

Statement of all outstanding water rights on the Tuolumne River, and the proposed method of providing for the protection thereof, by Percy V. Long, city attorney.

Preliminary report on the necessities of the Metropolitan water district, San Francisco region, by Prof. Charles D. Marx.

Report on discharge of Calaveras and Alameda Creeks, by C. D. Marx, C. G. Hyde, and C. E. Grunsky, consulting engineers.

Report on conditions of water supply of Niles Cone, Alameda County, Cal., by J. H. Dockweiler, consulting engineer.

Report on the American-Cosumnes project as a source of water supply for San Francisco and adjoining communities, by J. H. Dockweiler, consulting engineer.

Report on the water yield of the Hetch Hetchy, Cherry Creek, and Lake Eleanor watersheds, by Cyril Williams, jr., civil and hydraulic engineer.

Report on water supply of the Alameda Creek watershed, by Cyril Williams, jr.

Studies of a 60,000,000 gallons daily water supply for San Francisco from Lake Eleanor and Cherry Creek, with power development for municipal purposes, by Marsden Manson, city engineer.

Report on the Mokelumne River as a source of water supply for San Francisco, by C. E. Grunsky, consulting engineer.

Report on Feather, Yuba, Stanislaus, and Eel Rivers as sources of water supply for San Francisco, by C. E. Grunsky, consulting engineer.

Objections were filed as follows:

Review and criticism of reports filed by San Francisco with the Board of Federal Engineers, from June 30, 1912, to August 1, 1912, by George Edwards.

Letter, dated August 31, from George A. Aldrich, on turbidity and discoloration of Tuolumne River water.

Briefs by Sierra Club, protesting against Hetch Hetchy grant.

Brief of William H. H. Hart.

Copies of reports previously filed and of propositions made to San Francisco by Sierra Blue Lakes Water and Power Co. (Mokelumne River supply).

Report on Turlock and Modesto Irrigation Districts (2 volumes), by H. M. Crowe and Burton Smith.

Report on the McCloud River project; revised plan and proposition in reply to a criticism of former report.

Report of National Park Electric Power Co.

Report on water supply of San Francisco, by Gen. H. M. Chittendon and A. O. Powell.

Reply to Cyril Williams's report on water supply of the Alameda Creek watershed by G. G. Anderson.

Report on the resources of the Alameda system, by Herman Schussler, consulting engineer, Spring Valley Water Co.

Report on a supply from the Yuba River, by Samuel Storrow.

General report by Spring Valley Water Co., on its system and possible future extension, including subreports by several engineers, in reply to statements made in the Freeman report. This is a printed report.

Additional reports were received about November 20, as follows:

Turlock and Modesto Districts, J. H. Dockweiler.
McCloud River, M. J. Bartel, assistant city engineer.
Livermore and Sunol Valleys, Myron L. Fuller, consulting geologist.
Niles Cones, J. H. Dockweiler.
Alameda Creek System, Cyril Williams, jr.
Alameda Creek System, G. G. Anderson.
Alameda Creek System, J. R. Freeman.

At the hearing of November 25 the city was directed to submit a comparative analysis of costs of the alternative projects based on unit standards; also data as to cost of a filtration plant in connection with the Hetch Hetchy project.

The Spring Valley Water Co. was directed to make an estimate of cost of development as proposed by company.

In accordance with these instructions reports were filed as follows:

Cost estimate on the McCloud River project, by M. M. O'Shaughnessy, city engineer of San Francisco.

Report on comparative cost estimates for several sources of supply as alternatives to the Hetch Hetchy project, by John R. Freeman, consulting engineer to San Francisco.

Estimate of cost of constructing the Hetch Hetchy Dam to a height of 200 feet, so that the excess capacity may be used for irrigation, by M. M. O'Shaughnessy, city engineer.

Estimates of cost for further development of the Spring Valley Water Co.'s resources, by F. C. Hermann and by Herman Schussler, chief and consulting engineer, respectively, of the Spring Valley Water Co.

Estimate of cost for a supply from the Yuba River, by G. A. Elliott, superintendent of operation and maintenance of the Spring Valley Water Co.

Estimate of cost of Mount Diablo Range tunnels, according to the Freeman plan for the Hetch Hetchy Aqueduct, by William Mulholland and J. B. Lippincott, chief and assistant chief engineer, respectively, of the Los Angeles Aqueduct.

Estimate of cost for a supply from the McCloud River, by Rudolph W. Van Norden, consulting engineer to the Mount Shasta Aqueduct Corporation.

General statement and discussion of the water-supply situation, by Luther Waggoner, consulting engineer to the Turlock and Modesto Irrigation District.

Copy of a letter from J. C. Shinn to Supervisor Koshland, on the question of taking further water from the ground water sources of the Spring Valley Water Co. on the east side of the bay.

Communication from Francis Burton Harrison, M. C., Sixteenth New York district, suggesting the Merced River in connection with the Tuolumne as a source of water supply.

Paper by F. C. Hermann, showing that standard methods, used by J. R. Freeman elsewhere, were used by Spring Valley Co.'s engineers in estimating yield of Alameda Creek.

Supplemental report by John R. Freeman, January 30, 1913.

Letter from mayor of San Francisco, January 14, 1913, explaining permit asked for.

Supplemental letter of February 1, 1913, from mayor of San Francisco, inclosing modification of permit.

Letter of February 3, 1913, from officials of Turlock-Modesto Irrigation Co., asking for modification of permit.

Report in triplicate of F. C. Hermann, chief engineer of the Spring Valley Water Co., upon result of measurements of stream flow of Alameda Creek, made at Sunol Dam from January 15 to January 18, 1913.

Letter addressed on February 7, to the department, transmitting resolutions, suggestions, and criticisms by the Board of Supervisors of Stanislaus County, Cal.

"Notes on reports of the Spring Valley Water Co., filed with the advisory board of engineers December 23, 1912, showing that the company has grossly exaggerated the possibilities of its source of supply," by M. M. O'Shaughnessy, city engineer.

Notes on Yuba River, by M. M. O'Shaughnessy, city engineer.

Besides the reports mentioned, a number of communications have been received bearing on the several phases of the investigations.

In order to enable the board to carry out its instructions as to independent investigations, the services were secured of Mr. H. H. Wadsworth, assistant engineer, Engineer Department, United States Army. Mr. Wadsworth had been employed for about seven years previously under the Engineer Department, United States Army, on work in connection with the California Débris Commission and with river work in California, and is familiar with the general water-supply conditions in California. A general examination was made by him of all sources of water supply, and he personally inspected all the more important sources and surveyed many of the proposed reservoir sites; his report, prepared under instructions from the board, is appended. The board has considered carefully the data given in this report, as well as the documents submitted by the city and by the various opposing parties.

During the summer of 1911 the board personally visited the Spring Valley Water System; the Hetch Hetchy and Lake Eleanor reservoir and dam sites; Lake Vernon; Cherry Creek; the principal reservoirs on the Mokelumne River; the suggested reservoirs on the Yuba; the Sacramento and the San Joaquin Rivers.

During August, 1912, the board inspected the People's Water Co.'s plant for supplying Oakland and the other transbay cities; the Hetch Hetchy reservoir and dam site a second time; the Tuolumne Meadows and other camping sites in the Tuolumne watershed; and the Turlock-Modesto irrigation district. One member of the board inspected the McCloud watershed and the Feather River watershed.

PRESENT WATER SUPPLIES OF SAN FRANCISCO AND OTHER BAY CITIES IN PROPOSED METROPOLITAN WATER DISTRICT.

While the order of May 27, 1910, is directed to the city and county of San Francisco, and while most of the work done has been by San Francisco, yet the order contemplates that the water supply of the adjoining bay cities shall also be included in the investigation. This will comprise the territory from San Francisco around the bay including San Jose to the city of Richmond. While this includes a number of political entities, which may always remain distinct, they are so topographically related that a common water system would doubtless prove of great benefit, and steps are being taken by some of them at least to consolidate into a general metropolitan water-supply district. Several of the communities, such as Oakland, Berkeley, Alameda, San Jose, Redwood, Palo Alto, have, through their mayors and councils, already indicated their desire to participate in the benefits of a common Sierra or mountain supply.

The following figures as to present population and water consumption of the communities around San Francisco Bay can be taken only as general, but are sufficiently accurate for the purpose. Details are

found in the report, with appendices, furnished by the city of San Francisco. The population and water consumption are based on the year 1910.

San Francisco—City and county.

Population		417,000
Consumption (general supply)	M. G. D.	37.6
Per capita daily	gallons	90

In addition, there is a supply from wells, in part private and in part public, estimated at 5.5 M. G. D., which would bring the per capita consumption to about 103 gallons daily. There is no municipally owned water supply, except for a very small section. The 37.6 M. G. D. are supplied by the Spring Valley Water Co., partly from the San Francisco peninsula system and partly from the Alameda Creek system.

Part of San Mateo County, including several small cities and suburban and rural communities.

Population:		
Urban and suburban		18,745
Rural		6,255
		25,000
Consumption	M. G. D.	15
Per capita daily	gallons	600

The supply is mostly from wells, though a small quantity is from surface supplies. It is furnished in part by municipal plants, in part by water companies, and in part by private wells. A large proportion is used for irrigation, especially in the cemeteries and truck gardens.

Santa Clara County, including city of San Jose, other small cities, and suburban and rural communities.

Population:		
Urban and suburban		58,000
Rural		20,000
		78,000
Consumption, urban and suburban	M. G. D.	9.6
Per capita daily	gallons	165
Consumption, rural	M. G. D.	1.5
Per capita daily	gallons	75
In addition there is used for irrigation	M. G. D.	42.5

The water is supplied in part from surface water, but largely by wells. It is furnished through municipal plants, private companies, and private wells.

Parts of Alameda and Contra Costa Counties, including Oakland, Alameda, Berkeley, Richmond, and other cities and rural communities.

Population, mostly urban		253,000
Consumption	M. G. D.	26.9
Per capita daily	gallons	106
This is supplied—		
From surface sources	M. G. D.	10.3
From underground sources	do	16.6

It is furnished in part by several private water companies, of which the principal is the People's Water Co., and in part by nearly 4,000 private wells, aggregating about 6.4 M. G. D.

The above estimates give a total population of the bay communities of about 773,000 and a total water consumption of about 133 M. G. D. It is not practicable to draw the line accurately between water used for municipal purposes and that used for irrigation, but as nearly as can be estimated the municipal consumption amounted to about 85 M. G. D., equivalent to 110 gallons per capita, and the balance, 54 M. G. D., was used for irrigation.

FUTURE SUPPLY NEEDED.

This can be only approximately estimated, as the quantity must be based on probable population and on probable per capita use at the date for which the supply is estimated.

In one important respect the situation in California requires special consideration. In eastern cities, where there is little consumption of water except for municipal supply, it may be safely assumed that if at any future time additional water is needed the existing sources will usually be available as at present. In California all water has great value. Due to the large extent of arid and semiarid land that can be made fertile by the use of water, irrigation is assuming great importance; due to lack of coal and the opportunity for economical water-power development, the use for the latter purpose will surely be greatly extended. In a relatively few years practically all available water will doubtless be appropriated for one or the other purpose, and it will then be possible to obtain it for municipal use only at great cost and damage to existing communities and industries. It is, therefore, necessary to-day for the cities of California to look further ahead than in most other parts of the country, and to take such steps that in the future when they may need the water they shall have the right to it. For this reason it is believed that in making provision for the future supply of San Francisco and other bay cities a source should be selected if possible that is capable of supplying the needs of the communities for the balance of this century. Such a course would seem both wise and reasonable, provided it involves no sacrifice of economy.

In the report of Mr. John R. Freeman is given an estimate by Prof. C. D. Marx, Stanford University, of the amount of water needed by the end of this century. The population of the bay region in the year 2000 is estimated at 3,632,000 and the water consumption, outside of rural communities, at 130 gallons daily per capita. This gives a total of 441 M. G. D. The irrigated land is estimated at 95.000 acres and the water necessary at 95 M. G. D. This gives a total for consumption and irrigation of about 540 M. G. D. needed by the year 2000.

This estimate of a population of 3,632.000 is adopted as reasonable.

The per capita consumption in the different cities of the United States varies so that no definite standard can be adopted. Tables show it to run as low as 60 gallons and as high as 300 gallons per capita. Though efforts are being made generally in cities to reduce consumption, and though much has been accomplished, the fact still remains that the amount consumed is and probably will continue to be large, and therefore 130 gallons per capita is not considered an unreasonable assumption.

With the above estimate of the water supply that will be needed by the year 2000 is at best only a rough approximation, it is considered sufficiently accurate for practical purposes. If the population or the consumption, or both, increase at a faster rate than estimated, then the limit of the supply provided will be reached a few years before the end of the century; if the increase is less rapid, then the supply will suffice for a few years longer. In any case an ample supply will have been provided for many years to come.

POSSIBLE DEVELOPMENT OF SOURCES NOW IN USE.

As stated in preceding paragraphs, the amount of water now used by the bay communities is about 133 M. G. D., including that used both for municipal and irrigation purposes. The amount needed by the year 2000 is estimated at 540 M. G. D. So that about 400 M. G. D. additional must either be developed from existing sources or brought in from others. No such amount can be secured from existing sources, though the exact amount of their possible development is uncertain, as the supplies are largely underground. It does not appear essential for the purposes of the board that accurate figures should be secured, as it is only necessary to know that outside sources must be sought for and, in general, how much will be needed. The communities surrounding the bay will doubtless develop their local sources to the utmost economical point, having in view both city supply and agriculture, and seek outside sources only when local ones prove insufficient.

San Francisco and county.—The well supply of 5 to 6 M. G. D. can not probably be made greater. As the city grows and is paved more and more, the rainfall on the built-up portions will be carried off directly and not sink in the ground. While probably most of the well water comes from a distance, the total quantity available will not increase as the city is built. Besides, well water taken within the limits of a city can not generally be considered as a satisfactory and safe source of house supply without treatment.

Spring Valley Water Co.—The possible development of the resources of this company has been the subject of much investigation and comment and the results arrived at differ greatly. In the peninsula system which supplies surface water, the amount available can be determined with reasonable accuracy. In the Alameda Creek system, where the supply is largely underground, it can not readily be measured, and the amount that can be taken is further complicated by the need of the land for irrigation, both surface and subsurface. The productiveness of the soil is dependent on the height and permanency of the water plane, and this can not be seriously altered without causing damage to agriculture. The Spring Valley Water Co. estimates that 160 M. G. D. additional can be developed from its system, as follows:

	M. G. D.
Coast streams not now used	50
Calaveras Reservoir and Upper Alameda Creek	60
Lower Alameda Creek supplies	50
Total	160

The cost of these developments has been estimated by Mr. Herman Schussler, consulting engineer, and Mr. F. C. Hermann, chief engineer, of the Spring Valley Water Co. The amounts arrived at

are substantially the same in the two estimates. Those of Mr. Schussler, which are slightly larger, are as follows:

Coast streams	$9,684,000
Calaveras	8,790,900
Lower Alameda	3,431,800
Total	21,906,700

This includes overhead charges.

The water company estimates that 21 M. G. D. can be obtained from the Coyote River for supplying the city of San Jose at a cost of about $1,000,000. (See report of Mr. Hermann.)

The water company further estimates that about 20 M. G. D. can be obtained by pumping at Alviso and Revenswood. The board considers this a doubtful source of supply except temporarily as an emergency, owing to the liability of injuring agriculture and to the proximity to sea water.

These estimates as to possible amount of development are not agreed to by the engineers representing the city of San Francisco either as to amount of water or cost. Mr. John R. Freeman states that about 50 M. G. D. might be developed from the transbay sources, but doubts the possibility of taking more than that amount on account of injury to agriculture and the local need of water. Other engineers give other estimates which differ greatly. The variation in estimates of engineers as to amounts is due largely to what they consider legitimate development. The absolute saving of every possible drop of water may be very different from a reasonable and economical development. The cost might become so large as to be poor engineering practice.

The city claims that adverse possession of water rights in the upper parts of some of the streams affects the rights of the Spring Valley Water Co. This would, however, only lessen the value of the water company's holding and not affect the amount of water tributary to the system. It should be further noted as affecting legal restraints that all the country surrounding San Francisco Bay is included in the proposed water district, and that even if it be not advisable to pump too deeply, underground water can be considered as part of the water available.

In view of the lack of definite knowledge as to the water run-off and the many assumptions that must be made as to the capabilities of the underground storage, the board does not believe it possible or desirable for it to express an opinion as to the possible ultimate yield. An assumption of what may be considered a safe basis of development seems sufficient for the purposes of this report and even this assumed amount may not be found economically practicable and, further, may be prevented by the courts. For example, while the estimates of the Spring Valley Water Co. for the development of the coast streams, to a reasonable extent at least, appear to be economical, the company has taken no steps to actually make use of this water. The board believes to be reasonable and sufficient for this report the following estimates of the development of the Spring Valley Water Co., including the water supplied at present:

	M. G. D.
Present peninsular system	19
Additional coast streams	25
Alameda system	87

The present peninsula system development is now about 22 M. G. D. Of this about 3½ M. G. D. comes from Lake Merced, which will probably in the future become unsuitable for a city supply on account of the proximity to San Francisco.

Part of San Mateo County.—From the report of Prof. Marx, the present supply of this district is about 15 M. G. D., mostly underground. He estimates that the underground sources can not be much more drawn upon, but that about 5 M. G. D. may be obtained from surface sources.

Part of Santa Clara County.—The amount now drawn from surface and underground sources is between 50 and 55 M. G. D., a large part of which is used for irrigation.

Prof. Marx states that it has been estimated that about as much additional could be obtained from storage on a number of small creeks, but that the Supreme Court of the State of California has ruled that the waste can not be stored, and that therefore all additional water needed must be brought from the outside.

Parts of Alameda and Contra Costa Counties.—The present supply is 26.9 M. G. D. While it is possible that some additional water can be obtained by extending the surface system and by developing existing or boring new wells, it is evident that the present sources of supply are near the limit of development. Any considerable extension of the well system, such as at the Niles Cone, would doubtless so injure agriculture as to prevent its being permitted. Furthermore the use of water originating so near to large communities may some day prove inadvisable.

To sum up: (*a*) All present near-by sources of water supply for the bay communities are now drawn on nearly to their economical limit with the exception of the Alameda system of the Spring Valley Water Co. and the coast streams; and (*b*) the total estimate of the economical development possible, including the amount now used, is:

	M. G. D.
Spring Valley Water Co. resources	131
San Mateo County	20
Santa Clara County	55
Parts of Alameda and Contra Costa Counties	27
	233

The board wishes to emphasize the fact that it accepts these figures as to possibility of development of local sources only in the most general way. Sufficient data are not available to enable definite estimates to be made nor has the board had the time or facilities to make independent investigation.

The board does not, however, consider it essential for the purposes of this report to have accurate knowledge of quantities. There are sufficient data for the board to be able to state that outside sources of water supply must be obtained to provide the bay communities with sufficient water before the year 2000 A. D.

The city of San Francisco assumes the additional amount necessary as 400 M. G. D., being the difference between the 540 M. G. D. estimated as needed in the proposed metropolitan water district and the amount that it claims can be developed from near-by sources. The city also states that in time 500 M. G. D. additional from outside sources might be used with advantage.

In the opinion of the board this is a very liberal estimate, and the board believes that with an economical and proper development of near-by sources 300 M. G. D. additional could probably be made to suffice until the end of this century.

In the projects that have been submitted to the board the amount of 400 M. G. D. from outside sources has been assumed, and therefore it is necessary to take this figure to make comparisons. Further, there can be no question but that the 400 M. G. D., if available, could be used to advantage for many purposes, such as to supply smaller communities on the line of the aqueduct, for irrigation and power.

The board believes that the city should take steps to acquire the necessary water and reservoir rights at once and develop them gradually as needed.

The board further assumes that all existing water supplies, except perhaps the private wells, will be acquired in connection with the proposed metropolitan water district.

The supervisors of San Francisco have made an offer of purchase to the Spring Valley Water Co., and the East Bay cities are considering the purchase of the People's Water Co. While the purchase of the private plants is not absolutely essential, it is so much to the interest of the communities as well as of the companies that it will doubtless be accomplished and in this report will be taken for granted in the determination of additional supplies.

AVAILABLE SOURCES OF WATER SUPPLY.

The source of supply which is desired by the city of San Francisco and approved by the other bay communities is popularly known as the Hetch Hetchy. The water is taken from the upper Tuolumne River within the high Sierras, and the system is to include reservoirs at Hetch Hetchy, Lake Eleanor, and other points of the watershed. From various examinations and reports it is believed by these communities that this water is as good as can be secured anywhere in the world, ample in quantity, and the most economical to obtain. There is a strong popular sentiment in its favor, and bonds have been voted by the city of San Francisco toward the construction of the necessary works. Certain purchases had already been made and other action taken by the city of San Francisco under the terms of the Garfield permit before construction work was stopped by the Secretary of the Interior when he directed the city of San Francisco to show cause why the Hetch Hetchy part of the permit should not be revoked.

As above stated, the city was further required by the Interior Department to investigate and report on all possible available sources of supply without the use of the Hetch Hetchy Valley as a reservoir. The required work was done by the city under the direction of the city engineer, who, up to his resignation, about the middle of July, 1912, was Mr. Marsden Manson. The city engaged the services of outside engineers and scientists, including Mr. John R. Freeman, of Providence, R. I.; Mr. Allen Hazen, of New York; Prof. C. D. Marx, Stanford University; Mr. Cyril Williams, jr., C. E. Grunsky, and Mr. J. H. Dockweiler, in addition to making use of reports submitted to the Spring Valley Water Co. by Mr. Herman Schussler, Mr. F. C. Hermann, Mr. Wm. H. Mulholland, Mr. J. B. Lippincott, and others, and the geological investigations of Mr. J. C. Branner.

The final reports have been made by and under the direction of Mr. John R. Freeman. The reports have covered all sources of water supply that are considered as available. Some of the reports, notably those on the Tuolumne and Sacramento Rivers, have been thorough and complete. Others have been much less so, due largely, it is thought, to the lack of importance and impracticability, from the point of view of the city authorities, of any source of supply other than the upper Tuolumne.

At the hearing of November 25, the city was directed as before stated, to make further estimates as to the cost of supplies other than the Tuolumne and to place all estimates as far as practicable upon the same basis of calculation.

In passing upon what is meant by an available source of water supply, the board assumes the following conditions:

First. The water yield shall be sufficient under the most severe conditions of run-off to meet the requirements of the communities, and of good potable quality.

Second. The water can be collected and delivered with reasonable economy.

Third. No injury shall be caused, without proper compensation, to any industries or lands that have a just claim upon the water.

The sources considered of possible additional water supply for the bay cities are as follows:

(*a*) Eel River.
(*b*) Putah Creek.
(*c*) Clear Lake and Cache Creek.
(*d*) McCloud River.
(*e*) Sacramento River.
(*f*) Feather River.
(*g*) Yuba River.
(*h*) American River.
(*i*) Lake Tahoe.
(*j*) Mokelumne River.
(*k*) Stanislaus River.
(*l*) San Joaquin River.
(*m*) Tuolumne River.

These sources are described in more or less detail in the reports submitted by the city and are discussed in the appended report of Mr. H. H. Wadsworth. Only a brief description of most of them will be given in this report.

(*a*) *Eel River* rises in Mendocino County and flows northwest to the Pacific. Investigations show it could be developed to supply from 170 to 200 M. G. D. of suitable water. As this amount is not sufficient and as it would be unduly costly to develop this in connection with other supplies, it is not considered available and no estimate of cost has been made.

(*b*) *Putah Creek*, a small branch of the Sacramento River, rises in the Coast Range. Its discharge is inadequate and there is no available storage.

(*c*) *Clear Lake and Cache Creek.*—Cache Creek rises in the Coast Range and is tributary to the Sacramento River. Clear Lake empties into Cache Creek. Their use would interfere with irrigation development and the water is not of the excellent quality of other sources.

(*d*) *McCloud River* rises on the south side of Mount Shasta and, uniting with the Pitt River, forms the principal tributary of the upper

Sacramento. Its least flow is about 1,200 cubic feet per second, or about 770 M. G. D., amply sufficient for all possible needs The water appears to be good and pure. No reservoir would be necessary as far as quantity is concerned. If desired to hold in reservoirs for sanitary reasons, suitable sites could doubtless be found in Contra Costa County if not in the McCloud River basin. This source is considered a feasible one and it will be discussed in greater detail later in this report.

(*e*) *Sacramento River.*—The plan in this case would be to pump water from near Rio Vista, the point nearest to San Francisco at which it is always free from sea water, and filtered before delivery. The cost of delivery would be relatively great on account of the filtering and pumping. The water, though harder than Sierra water, would be good in quality and ample in quantity. As population and irrigation increase in the valley, the quality is liable to deteriorate. This is considered a perfectly practicable source, if no better is available. In cost for 400 M. G. D. and in quality it is inferior to the Tuolumne supply.

(*f*) *Feather River.*—This is the principal tributary of the Sacramento River. The supply for city purposes can be made ample by storage. On Indian Creek, a branch of this river, Indian Valley affords an excellent and economical reservoir site. The city has made no surveys nor estimates as to the cost of the use of this valley. The elevation is about 3,500 feet.

From such data as are on hand, based on a survey made in connection with the work of the California Débris Commission, the cost of a reservoir in Indian Valley is estimated at $2,384,000. This estimate proposes a dam 120 feet high above low water of the creek, and the reservoir would have a capacity of 600,000 acre-feet or 196,000 million gallons. Indian Valley comprises about 13,600 acres of good agricultural land largely devoted to dairying, and three small towns, of which two would be flooded by the construction of the reservoir. The existing water rights are not known. From the Geological Survey map it would appear that the watershed would give the needed supply of water. To protect the water a continuous aqueduct would have to be built from Indian Valley, and this, on account of the ruggedness of the country would necessitate, probably, a more or less continuous tunnel for about 50 miles, which would necessarily be very costly. On account of existing water-power developments it is questionable if the amount of water could be taken out of the river above the power installation. If allowed to flow in the river the water would doubtless need to be filtered. If filtration is undertaken the lower Sacramento River offers the advantage of shorter aqueduct and more ample supply without storage; in other words, will be more economical. As there are other possible available sources superior to the Feather River, it has not been further considered by the board.

(*g*) *Yuba River.*—The Yuba River is a branch of the Feather River. By a system of natural and artificial reservoirs on the Middle and South Forks a supply of 164 M. G. D. of suitable water can be secured at a reasonable cost. While the quantity is not sufficient the Yuba might be combined with other sources so as to give a satisfactory supply.

By taking the full flow of the Yuba River a sufficient quantity of water for city purposes might be obtained. The point of diversion, however, would be necessarily so near the mouth and at such a low elevation that pumping would be required. As the storage reservoirs would have to be much higher up in the mountains the purifying effect of storage would be lost and filtration be advisable. As compared with several other sources the use of the full flow does not appear advantageous. Much of the flow has been taken for power and irrigation and the cost of extinguishing these rights has not been determined.

(*h*) *American River.*—This is a tributary of the Sacramento River, entering it at the city of Sacramento. Immediately south of the watershed of the American River lies the watershed of the Cosumnes, a tributary of the Mokelumne. Owing to the topographical situation of the two watersheds they have usually been combined when considered as a source of supply for the bay cities. This apparently gives the most satisfactory results and has been the method considered. It is estimated that about 220 M. G. D. of entirely suitable water can be obtained from these sources. By combination with other sources these could be made an available source of supply. A thorough discussion of this source is made in report of Mr. J. H. Dockweiler.

A further possible development of water from the North Fork of the American River has been suggested and is known as the Giant Gap supply. This has not been reported on by the city, for the apparent reason that it can not be combined economically with the rest of the North Fork supply.

(*i*) *Lake Tahoe.*—This lake lies in part in California and in part in Nevada. Its outlet, the Truckee River, passes through California into Nevada. The water is extensively used for power and irrigation purposes, especially in the latter State, where it is much needed. The quality is excellent and the storage capacity good. The average supply is about 275 M. G. D. On account of the use made of these waters elsewhere, especially in Nevada, it is not thought they could be diverted to San Francisco, and the lake is not considered an available source of supply.

(*j*) *Mokelumne River.*—This river is a tributary of the San Joaquin. It has been given consideration as a source of supply for San Francisco since about 1877, and recently has been offered by the Sierra Blue Lake Water & Power Co. The waters are used to a certain extent for power and irrigation, and it is probable that in the future a much larger use would be naturally made for irrigation. The amount that could be obtained has been variously estimated by the company and others up to 200 M. G. D., and even more. Most of these estimates appear too large, and probably only about 128 M. G. D. could be counted on. It could be used in connection with other supplies.

(*k*) *Stanislaus River.*—This is one of the tributaries of the San Joaquin. Its waters are quite fully utilized by power companies and for irrigation, and only about 57 M. G. D. could be counted on as available for water supply. It could be used in connection with other supplies.

(*l*) *San Joaquin River.*—The development of this source would be similar to that of the lower Sacramento River by filtration and pumping. As the water of the San Joaquin is inferior in quality and quantity to the Sacramento, with no advantage as to cost, it need not

be further considered except for possible temporary use during construction of the aqueduct.

(*m*) *Tuolumne River.*—This is one of the main branches of the San Joaquin. It is claimed that from this river the full 400 M. G. D. can be obtained after making allowances for all existing rights. The quality of the water is excellent and the cost of delivery relatively small. It is the source of supply desired by San Francisco and the other bay communities. Lake Eleanor and Cherry Creek are a part of the Tuolumne system.

There are other rivers to the south, such as the Merced and the upper San Joaquin, which might, if it were necessary, be used. Their distance from San Francisco and their present use for irrigation render them, however, inferior as compared with other available sources.

From the above descriptions the practically available sources are considered to be as follows:

	M. G. D.
1. McCloud River	400+
2. Sacramento River	400+
3. Tuolumne River	400+
4. Yuba River	164
5. American-Cosumnes	220
6. Mokelumne River	128
7. Stanislaus River	57

Thus from each of three possible sources the full supply of 400 M. G. D. could be obtained. In the other cases, combinations could be made, such as the American-Cosumnes, Mokelumne, and Stanislaus, or else Lake Eleanor, Cherry Creek (tributaries of the Tuolumne), Stanislaus, and Mokelumne.

It is understood that these figures do not represent the total flow of these streams. Each of the four last named, except perhaps the Stanislaus, would probably give enough water for the city if the total flow were utilized. Due to existing rights, to location of reservoirs, to questions of pumping and filtration, etc., it is considered that it would be more economical for the city to combine several of these rivers rather than to take all the supply from a single one. Therefore the cost under the latter assumption has not been considered necessary to determine.

It is further understood that the seven sources named are not the only possible sources. They appear to be the most available and it is, therefore among them that a supply would be sought. There would seem to be no necessity then of determining with further accuracy the cost and conditions of other sources as they would not be the sources developed if the Tuolumne River became unavailable.

McCLOUD RIVER.

The McCloud River is a branch of the Pitt River, which itself is a tributary of the Sacramento. McCloud River rises on the southern and southeastern slopes of Mount Shasta. It flows in part from glaciers and in part from large springs. The water is clear, cold, and palatable. The inhabitants of the valley drink it at any point and consider it of first-class quality. At some times of the year, said to be for only short intervals, it assumes a milky appearance. This seems to be due to a small tributary, Mud Creek,

which at times carries considerable lava sand. On the day of the inspection by a member of the board, Mud Creek was carrying a large amount of this sand and the river was quite milky in appearance. It is not thought that this affects the hygienic qualities. It seems probable that by damming Mud Creek and forcing the water to percolate through the soil this sand could be held back, or the water could be confined in a reservoir and allowed to settle. The minimum discharge of the McCloud River being about 1,200 cubic feet per second, or 770 M. G. D., the flow is ample without storage.

The rights to the flow of the McCloud River are claimed by the Mount Shasta Aqueduct Corporation, represented by Mr. R. P. Doak. Mr. Doak has offered to build the aqueduct or to sell the rights claimed by the corporation he represents to the city, though the offer is indefinite, being based on the estimated saving in cost over the Tuolumne project. The latest offer of the corporation proposes only selling its rights. The corporation further proposes to deed to the city so much of the land it owns within the watershed above the dam as might be the source of future contamination. This is understood to be the cut-over forest lands, which can be secured at a relatively small cost. The owners of the large individual holdings (summer residences and clubs) would doubtless readily subscribe to any regulations which might be adopted to prevent contamination of the water supply. A considerable portion of the watershed lies within the national forests. The corporation proposes delivery by gravity of 400 M. G. D. at an elevation of 300 feet into reservoirs having a capacity of 30,000 million gallons, on Pinole and San Pablo Creeks in the Contra Costa hills north of the city of Berkeley. From these reservoirs the conduit would have a capacity of 400 M. G. D. to Oakland; thence across the bay to San Francisco a conduit carrying 200 M. G. D., and delivery at an elevation in San Francisco 200 feet above sea level.

The city of San Francisco presented unfavorable reports on this source, and it is further unfavorably commented on by Mr. John R. Freeman. The reports are not, however, either comprehensive or complete.

Mr. Freeman dwells upon the possibility of infection of the water. With a large part of the watershed owned in fee by the city and another part within the national forest, proper policing should present no great difficulties and additional protection will be given by the proposed storage reservoir north of Berkeley. There would be no power development under the plan submitted, though possibly some could be obtained by dams in the McCloud River, which question has not been thoroughly investigated.

The withdrawal of so much water from the Sacramento River might at times affect navigation and irrigation, as the total low-water discharge at the city of Sacramento is only about 6,000 cubic feet per second. Navigation could be provided for notwithstanding the withdrawal of the water, but at considerable expense. While it is thought that in time most of the waters of the valley of California will be needed for irrigation, the Sacramento Valley is better provided with water than is the San Joaquin Valley, and has a somewhat higher rainfall. As far as known there are no irrigation rights which would seriously interfere with the use of the water by the city for domestic purposes.

Furthermore, it is stated by the Mount Shasta Aqueduct Corporation that storage reservoir sites can be found on the lower McCloud River by the use of which the low water flow can be augmented, though the corporation has made no definite surveys. The city of San Francisco, since the hearing of November 25, has made further examination of the McCloud River and a reconnoissance survey of reservoir sites, and reports a possible site on the McCloud River with an available capacity of 53,100 million gallons.

It was claimed by the city at the hearing before the Secretary of the Interior that an act of Congress approved May 9, 1906 (see Stat. L., 185), giving the Central Canal & Irrigation Co. (to which company the Sacramento Valley Irrigation Co. is understood to be successor), the right to take 900 cubic feet of water from the river for irrigation when the river is 2 feet above low water, would prevent the city from taking 400 M. G. D. at such times as the river approaches this stage. This is not thought to be necessarily the case. The act of Congress is of a permissive character, its essential object being to prevent damage to navigation, and it would hardly be construed as forbidding any one taking water above the intake of the irrigation company. At the same time, however, there might be some legal complications.

In this connection it may be proper to note that on July 12, 1912, application was made by Mr. R. T. Stone, of Davis, Cal., for permission to take out 800 second-feet of water at a point on Sacramento River between the mouth of Feather River and the city of Sacramento, about 12 miles above the said city. The Sacramento and Feather River board, which is composed of three officers of the Corps of Engineers and which has charge of navigation on these rivers, recommended favorable consideration of this application up to the amount of 800 cubic feet per second, subject to certain conditions, one of which contemplated that the land for which the water was to be used should be actually under cultivation and irrigation. No limitation regarding the withdrawal of the water was suggested by the board when water was low in the river.

The Chief of Engineers, in order to adhere to the practice indicated in the aforementioned act of Congress, suggested to the board the limiting of the time of taking water to stages of the river of 2 feet and over above low water. The application of Mr. Stone was finally given favorable consideration by the department, and permission to divert for irrigation purposes, not to exceed 800 second-feet of water at a point about 12 miles above the city of Sacramento, was granted by formal instrument executed December 18, 1912. There were a number of conditions attached to this grant or privilege, primarily designed to protect and conserve the interests of navigation.

The question of obtaining a supply from the McCloud River thus becomes principally one of cost. In the latest report of Mr. Freeman an estimate is submitted from calculations made by Mr. Horace Ropes, as follows:

First stage	200 M. G. D. to be completed in 1920	$61,207,000
Second stage	90 M. G. D. to be completed in 1947	12,920,000
Third stage	110 M. G. D. to be completed in 1968	11,527,000
Total..	400 M. G. D	85,654,000

By discounting the costs back to 1920 at 4½ per cent, Mr. Ropes gives a total of $66,534,000.

By compounding interest to 1968 he gives a total cost to the city of $550,976,000.

The city engineer of San Francisco makes estimates on two plans, the first according to the plan generally proposed by the Mount Shasta corporation, crossing the bay at San Francisco, the second by a higher level line, crossing the bay at Dumbarton Point.

The costs are given as follows in report submitted by Mr. John R. Freeman, January 30, 1913:

First line.

For 200 M. G. D.	$80,820,000
For 200 M. G. D.	7,730,000
Total	88,550,000

By discounting to 1920 the total is given as $82,880,000.

Second line.

For 200 M. G. D.	$91,740,000
For 200 M. G. D.	9,999,000
Total	101,739,000

By discounting to 1920 the total is given as $94,410,000.

In the summary submitted by Mr. John R. Freeman, he estimates as follows:

First stage,	220 M. G. D., 1920	$61,207,000
Second stage,	80 M. G. D., 1947	12,920,000
Third stage,	100 M. G. D., 1968	12,927,000
	400	87,154,000

This estimate, like Mr. Ropes's estimate above, provides for crossing the bay near Dumbarton Point.

The estimates prepared for the board by Mr. Wadsworth are as follows:

For 260 M. G. D.	$59,550,300
For 140 M. G. D.	5,400,800
400	64,951,100

By discounting to 1914 the total is $52,500,000.

If the Dumbarton crossing is used the costs are estimated at—

For 260 M. G. D.	$65,520,700
For 400 M. G. D., a total of	76,891,900

By discounting to 1914 the total is $58,100,000.

The difference between the estimates of Mr. Wadsworth and those submitted by the city lies almost entirely in the construction of storage dams on the McCloud River, which have not been considered by the board, and in assumed length of conduit. As previously stated, a storage dam on the McCloud River or adjacent streams is not necessary either for the purpose of supplying sufficient water for the city nor of purifying by storage. The flow in low water is sufficient, and purification if needed can take place in the reservoirs provided for in Contra Costa County. The only object of the reservoirs on the McCloud River would be to furnish water during low stages of the Sacramento for irrigation and other rights. As to length of conduit, the surveys are not sufficiently complete for accurate meas-

urements. It is a question of how straight the line may be, or how necessary it will be to follow in and out on contours crossing the many streams and valleys. It is thought that the estimate of Mr. Wadsworth may be too small in that particular, and an increase of 10 per cent is adopted. This would make the total cost about $71,000,000 for the bay crossing and $84,000,000 for the crossing at Dumbarton Point.

The city claims to foresee two great risks in the McCloud proposition, namely, the crossing at Carquinez Straits and at San Francisco Bay directly to San Francisco. While it is admitted that these crossings are difficult and that this project is in that respect inferior to those projects taking water from the tributaries of the San Joaquin and the Mokelumne, the crossings are not considered as impracticable. The crossing of the bay can be obviated, as above stated, by carrying the aqueduct across at Dumbarton Point, though with considerably increased cost.

SACRAMENTO RIVER.

This plan is discussed in detail in the report of Mr. Allen Hazen. He proposes to take water from near Rio Vista, with an emergency intake not far from Antioch. The water would be pumped to the filter beds near Antioch, crossing the Sacramento and San Joaquin Rivers. From the filter beds it would be pumped to the bay cities. Several routes to the east side of the bay and several different crossings of the bay are considered in the report. Mr. Hazen estimates the cost of installation as follows:

For 60 M. G. D.	$24,000,000
For 120 M. G. D.	42,000,000
For 180 M. G. D.	60,000,000

The cost of filtration and pumping to San Francisco is given as $17 per million gallons. Mr. Freeman adds $1,500,000 per 60 M. G. D. for a pumping station within the city and about $8 per million for pumping to delivery at an elevation of 280 feet above sea level, making the estimated cost of operation for 400 M. G. D. about $25 per million gallons, $10,000 a day, or $3,650,000 a year.

In Mr. Freeman's supplemental report of December 23, 1912, he gives the estimated cost as follows:

First installation, 60 M. G. D., 1917	$31,950,000
Second installation, 60 M. G. D., 1925	22,630,000
Third installation, 60 M. G. D., 1937	27,310,000
Fourth installation, 60 M. G. D., 1950	22,630,000
Total	104,520,000

Discounting these amounts to 1920, Mr. Freeman gives a total of $73,520,000.

The reason why this differs from Mr. Hazen's original estimates lies mainly in the assumption of different unit costs, so as to compare with the Hetch Hetchy plan, and in the construction of a conduit around the south end of the bay, in addition to one across the bay at San Francisco, in order to supply communities lying south of San Francisco and to be in reserve in case of accident.

In his summary of relative costs of various projects, as appears in his supplemental report of January 30, 1913, Mr. Freeman gives the cost of the Sacramento supply brought in via Dumbarton as follows:

First installation	145 M. G. D., 1920	$46,495,000
Second installation	130 M. G. D., 1947	35,481,000
Third installation	125 M. G. D., 1968	34,313,00
Total	400 M. G. D	116,289,000

The cost as estimated by Mr. Wadsworth for the board is as follows:

First installation	133⅓ M. G. D	$39,404,900
Second installation	133⅓ M. G. D	35,096,400
Third installation	133⅓ M. G. D	32,510,900
Total	400 M. G. D	107,012,200

If the conduit is carried around by Dumbarton Point the increase in cost will be about $11,940,800, making a total of $118,953,000.

The advantages of this source are the ample quantity, the doing away with a storage reservoir, the noninterference with any existing rights, the freedom from legal difficulties, and the shortness of the aqueduct.

The disadvantages are the high cost for the full amount, the large cost of operation, the dependence on filtering beds, the relative hardness of the water, its deterioration in quality as the country becomes settled. The crossing of the bay near the city of Oakland is longer, and in case of damage by earthquake the aqueduct would be much more difficult to repair than at Dumbarton Point, where the Tuolumne River Aqueduct would cross.

This crossing presents difficulties and dangers, mostly due to earthquake possibilities, but the board does not consider these as making this plan impracticable. The same danger exists to a greater or less degree with every source considered. The people of San Francisco would undoubtedly feel at first a certain apprehension from this cause. With the large amount of storage on the San Francisco Peninsula any danger of shortage, however, is largely eliminated.

Mr. Allen Hazen has submitted a full analysis of the water. This shows considerable hardness, which, while not affecting the wholesomeness of the water, makes it less desirable as a city supply. As appeared at the hearing of November 25, several experts believe that in a number of years, set at from about 50 to 100, it is probable that all cities will insist on filtering their supplies, from whatever source derived, due not so much to unwholesomeness as to the increased demand for a clear, odorless, perfect water. Even if such prove the case, however, the cost of filtering a silt-bearing supply like the lower Sacramento would be greater than for filtering a supply such as the McCloud or Tuolumne.

The figures of average hardness submitted by Messrs. Hazen & Whipple are as follows:

Boston	12	St. Louis (partially softened before use)	200
New York	35	Philadelphia	35
Catskill	20	Delaware	
Washington	83	Sacramento	56–62
Chicago	105	Tuolumne River:	
Cleveland	92	Hetch Hetchy	20
Superior	45	Lagrange	40
Pittsburgh	75	Spring Valley supply	100
Cincinnati	78		
Louisville	83		

YUBA, AMERICAN, COSUMNES, MOKELUMNE, AND STANISLAUS RIVERS.

The Yuba, the American, the Cosumnes, the Mokelumne and the Stanislaus rivers are of the same general nature. They all rise in the high Sierras, and the quality of the water is excellent. No one by itself would furnish economically the full amount necessary. The absolute control of the watershed such as would be the case with the upper Tuolumne, would not be practicable. Reliance would have to be placed on the State board of health.

It is considered that the quality of the water, if stored as is expected before use, would be good.

Yuba River.—It is estimated that about 164 M. G. D. can be obtained from the Yuba River. It can not be combined economically with any other of the sources considered available. A report on this source has been submitted by the city of San Francisco, but in the final reports and in the comparison submitted of the costs of the various supplies it has not been further considered by the city.

In a report submitted by the Spring Valley Water Co. the total cost of supplying 200 M. G. D. at an elevation of 165 feet in San Francisco is given as $38,224,460. It is proposed in addition to develop 191,677 horsepower at a cost of $18,113 757, valued at $20 per horsepower per year which capitalized at 4½ per cent, gives a value of about $85,000,000, or a net value of about $67 000,000.

The project proposes to bring the conduit across the Sacramento and San Joaquin Rivers near Collinsville and deliver in the San Antonio Reservoir of the Alameda Creek system, thence by the route proposed for the Hetch Hetchy project to the bay cities. A saving of cost of about a million dollars is anticipated from the gold-bearing gravels removed to construct the reservoirs. The cost of water rights is not included in this estimate.

Mr. Wadsworth's estimate for the board is as follows:

164 M. G. D., including water rights estimated at $4,000,000..... $61, 944, 000

The net value of a power development of 54,600 horsepower is given as $21,300,000. The line proposed crosses at Carquinez Straits and the Bay at San Francisco.

The differences in cost estimated by the company and the board are due to estimate of water rights, variation in estimated cost of storage dams, and in estimated lengths of necessary tunnels and pipes. The board does not consider that there is sufficient information on hand to express a definite opinion on the estimates, but believes that the high figures will more nearly represent the actual cost of construction.

LAKE ELEANOR-CHERRY-STANISLAUS-MOKELUMNE.

This project contemplates making use of the supply from Lake Eleanor and Cherry Creek, estimated at 215 M. G. D., and supplementing this by water from the Stanislaus, 57 M. G. D., and Mokelumne Rivers, 128 M. G. D. Reservoirs would be constructed within the mountains and the water collected carried to the bay communities as in the Hetch Hetchy project. The reservoir facilities are not as good as those of the upper Tuolumne. On the Stanislaus five reservoirs are estimated for, at a cost of $6,600,000 for dams; and on the Mokelumne, three reservoirs, at $8,401,000. This combination is estimated as follows in the final supplemental report of Mr. Freeman:

First installation,	225 M. G. D., 1920	$63,929,000
Second installation,	175 M. G. D., 1950	35,454,000
Total	400 M. G. D	99,083,000

The board's estimate is as follows:

Eleanor-Cherry,	215 M. G. D	$55,922,700
Stanislaus-Mokelumne,	185 M. G. D	43,324,100
Total	400 M. G. D	99,246,800

These estimates are practically the same.

The power development is estimated at 95,000 horsepower, valued at $33,000,000.

The relative cost of the reservoirs, the additional lengths of aqueduct, and the estimated value of water rights account for the increase over the cost of the Hetch Hetchy project.

AMERICAN-COSUMNES-MOKELUMNE-STANISLAUS.

This project contemplates combining the waters of the American and Cosumnes, 215 M. G. D., with the Stanislaus and Mokelumne Rivers, 185 M. G. D. The general plan of development would be similar to the previous plan discussed. The reservoir system would be costly, there being in addition to those mentioned above for the Stanislaus and Mokelumne, eight reservoirs on the American and Cosumnes, with estimated cost of dams $10,677,450. This combination is estimated by Mr. Freeman as follows:

First installation	220 M. G. D., 1920	$69,210,000
Second installation	180 M. G. D., 1950	52,794,000
Total	400 M. G. D	122,004,000

The board's estimate is as follows:

American-Cosumnes	215 M. G. D	$52,606.450
Stanislaus-Mokelumne	185 M. G. D	34,105,250
Total	400 M. G. D	96,711,700

The power development is estimated at 62,000 horsepower, valued at $24,300,000.

The estimate of the board for the source of supply is about the same as that of the Lake Eleanor-Cherry-Stanislaus-Mokelumne. That of Mr. Freeman is much larger. The information furnished the board does not admit adequate comparison of estimates. It is believed that the difference is due largely to assumption of route to be followed by the aqueduct. The estimates of the board are considered as relatively more nearly correct.

TUOLUMNE RIVER (PROJECT OF CITY OF SAN FRANCISCO).

This is the source of supply desired by the city of San Francisco and other bay communities, for which detailed estimates have been submitted, and for which a permit is asked for privileges within the Yosemite National Park.

The general project is as follows:

First. Purchasing the holdings of private water companies around San Francisco Bay and developing them to an economical use.

Second. Constructing an aqueduct to connect with the reservoirs in the Sierras.

Third. Constructing reservoirs in the Sierras, principally at Hetch Hetchy, Poopenaut Valley, Lake Eleanor, and Cherry Creek.

Fourth. Building roads and trails within the park for public use.

Fifth. Developing electric power.

The plan of development is a gradual one. The tunnels will be built full size to carry at least 400 M. G. D. Where there are several parallel pipe lines, they will be constructed as needs demand. The water will at first be taken from the flowing river about 12 miles below the Hetch Hetchy Dam. The dams will be built gradually and not to full height at once. Other parts of the system will be constructed from time to time, extending over about 50 years, thus giving interest on investment. The project is given in detail in the reports submitted by the city.

The cost of developing the Tuolumne system has been calculated in detail by the engineers of the city of San Francisco.

The latest figures, as given in report of Mr. John R. Freeman, of January 30, 1913, are:

First installation,	240 M. G. D., 1920	$44,664,000
Second installation,	160 M. G. D., 1947	17,490,000
Total,	400 M. G. D	62,154,000

These figures are considered by the board as too low, and from its calculations based on the plan presented by the city, keeping generally the same unit costs, the estimate is as follows:

First installation,	160 M. G. D	$37,501,400
Second installation,	80 M. G. D	13,910,800
Third installation,	160 M. G. D	25,955,200
Total,	400 M. G. D	77,367,400

The power valuation is estimated at $45,000,000 for 115,000 horsepower.

The principal reason for the difference in the figures presented finally by the city and those adopted by the board lies in the inclusion in the board's estimate of certain parts of the system which are considered necessary by the board, and which have been omitted in this estimate of the city, although included in the complete plan submitted by the city. These are such as the Lake Chabot Aqueduct and Dam, additional connections with San Francisco and Crystal Spring Reservoir, scenic road, etc. In addition, the board estimates about $1,000,000 for water rights.

The board believes that the figures presented represent more nearly the relative cost of construction as compared with other proposed systems than those finally presented by the city.

The city has submitted a modification of the Garfield permit asked for from the Secretary of the Interior in order to carry out its project. This permit will be discussed later in the report.

As the city of San Francisco and the bay communities appear to be a unit in their wish for the use of the Tuolumne River water, the objections to granting a permit need careful examination. It is admitted that domestic use is the highest use of water and also that it is of very great advantage for the city to have the watershed included in Government reservations.

The subject is considered under the following heads:

1. *Destruction of the floor of Hetch Hetchy Valley.*—The relative beauty of the Hetch Hetchy Valley in its two conditions—as it is at present or dammed up into a reservoir—seems to be a matter of individual opinion. It is admitted that the Yosemite Valley is as a whole more wonderful than the Hetch Hetchy Valley, but the floor of the latter is more diversified in its trees and flowers, and of at least equal beauty. Flooding the valley would destroy this floor and the falls of the Tuolumne at the head of the valley. The surrounding cliffs and falls would not be affected.

Lowering the reservoir will uncover the upper end and the sides. The portion uncovered will be unsightly especially if not cleared. The city will doubtless for protection of the water keep the exposed portion cleared. and furthermore the low stages in the reservoir will usually be in the early winter, a time of year during which there is at present no tourist travel, though when roads are opened this travel will doubtless develop. Moreover, the city does not propose, except under extraordinary conditions to uncover any portion of the main floor of the valley.

The Hetch Hetchy Valley is very little visited at present. The mosquitoes are bad in the early summer, and when they disappear the valley has become hot and campers seek higher altitudes. Even as a camping place for a night it is not much used to-day, though offering excellent grazing and a good place to start for the higher mountains. As the number of campers increase in the park, and as better roads and trails make the valley more accessible, it would doubtless be more and more used, and its loss as a camping place become more serious. On the other hand, the construction of hotels and stopping places, will facilitate the fitting out of campers; the building of better roads and trails will make traveling more easy and rapid and, according to the statements of the Sierra Club, there are many good camping places within easy reach of this valley. The possibilities of boating in the reservoir will be an additional attraction to certain classes of tourists.

The objectors to the granting of the permit to build the reservoir are not all animated by a desire to keep the valley intact. Some, such as certain irrigation districts; wish the site reserved for an irrigation reservoir.

An examination of reservoir sites in the Tuolumne watershed does not show enough sites to conserve economically the water available from this river without the use of the Hetch Hetchy Valley. It seems certain that in time there will be a strong demand that all water in this part of the Valley of California be conserved. This will necessitate the use of the valley as a reservoir, and therefore a delay of a few years in its use for that purpose does not seem important.

2. *Interference with camping above reservoirs due to possible contamination of water.*—Any development of the Hetch Hetchy Valley that would interfere with the public use of the region of the upper Tuolumne by campers should not be permitted if it can possibly be avoided.

The use of the water for irrigation would require no special safeguards to prevent pollution.

To protect the drinking supply the city proposes the conditions indicated in its permit. On account of its importance a communica-

tion to the city from Messrs. Hazen & Whipple, well-known experts on water supply, is quoted:

WASHINGTON, D. C., *November 25, 1912.*

PERCY V. LONG,
City Attorney, City of San Francisco.

DEAR SIR: In compliance with your request, we suggest that the following rules are appropriate and sufficient for the purpose of protecting the water in the Yosemite National Park proposed to be used for a municipal water supply for San Francisco under present conditions and under all future conditions of which we can conceive as probable, even should 10,000 or 20,000 people per year visit this watershed upstream from the proposed reservoirs of the city of San Francisco.

RULES.

(1) No human excrement, garbage, or other refuse shall be placed in the waters of any reservoir or stream or within 50 feet thereof.

(2) All sewage from permanent camps and hotels within the watershed shall be filtered by natural percolation through porous earth or otherwise adequately purified.

(3) It is forbidden to bathe, wash clothes or cooking utensils, to water stock, or in any other way pollute the waters within the limits of the Hetch Hetchy Reservoir or in the streams leading thereto within 1 mile of said reservoir or in the water from the reservoir between it and the "Early intake" of the aqueduct.

The first and second of the above rules are requirements of common decency and are needed in order to protect campers along the stream from the effects of pollution by other campers farther up the stream, whether or not the city were to use the water. The third rule is substantially the same as that now in force on the waters and creeks above the Sentinel Hotel in the Yosemite Valley. This rule, so far as it relates to the stream between the Hetch Hetchy Dam and the "Early intake," will not be needed after the construction of the aqueduct through this distance.

We are of the opinion that no rules are required forbidding fishing in the reservoir or against boating or bathing in the stream upstream from the reservoir and that there will never be need for prohibiting camping, skating, and sleighing on the Hetch Hetchy catchment area.

Rules against littering the ground at camping places are not essential for sanitary reasons, but are desirable for making the park more attractive when frequented by large numbers of campers, whether or not used for municipal water supply.

We can not conceive it as even remotely possible that future conditions could call for the exclusion of tourists or campers from this watershed when guarded by the above rules and a very few sanitary inspectors; and should popular sentiment or higher standards as regards water supply arise 50 years hence there will always remain the opportunity for filtration.

This gathering ground, however much frequented, will remain so superior to the average surface water supply of American cities that action by the city toward the exclusion of campers may be regarded as certain to never be called for.

Respectfully submitted.

ALLEN HAZEN.
GEORGE C. WHIPPLE.

The board has considered the situation existing in certain other cities of the United States.

In Portland and Seattle trespassing on the watersheds from which the city supplies are drawn is forbidden by law, but in both cases there is little storage.

In Los Angeles general regulations under State laws as to preventing pollution are relied on, though the city proposes to buy the riparian lands of the Owen River, mainly to protect its water rights.

In Boston the regulations require that all refuse be kept out of reservoirs and streams, forbid use of reservoirs for fishing, boating, bathing, etc., and require keeping perfectly clean the grounds for several hundred feet away from such reservoirs. It is stated that this gives satisfactory results.

In the water supply for New York City a large part of the watersheds is quite thickly inhabited. The unnecessary pollution of the

water is controlled by the State board of health. A restrictive line of about 500 feet around reservoirs is guarded, and inhabitants are required to see that no objectionable refuse finds its way into the water supply. There seems no restriction as to bathing, but as the banks of the reservoirs are generally owned by the city of New York, it is not probable much will take place. It is expected to filter largely in the future, for the main reason, it is understood, to make the water more palatable.

While the rules proposed by San Francisco will to a certain extent interfere with the indiscriminate use of the park, still, if many thousands of tourists should eventually go to the Tuolumne in summer and winter, restrictive rules would have to be adopted for the protection of the campers themselves, as the danger to them from pollution would be even greater than to the cities around San Francisco Bay.

It is feared by some that in the future more stringent regulations might be demanded by the city and that they would be difficult to refuse. This danger can be avoided by requiring the city to agree to filter or otherwise care for its water, if the regulations at present proposed prove not sufficient. An estimate of the cost of this filtration has been made by the board of $10,500,000, including cost of plant, $6,000,000, and capitalization at 4½ per cent of cost of operation.

The question of the purification of water by storage and the disappearance by this method of injurious bacteria has been the subject of considerable investigation and thought by engineers connected with the water supply of cities. It is the general opinion, as expressed in various textbooks, that a few weeks storage will cause the practical disappearance of the typhoid bacillus. The most elaborate experiments known to the board are those of Dr. A. C. Houston on the Thames River water, in England. While cold water is less efficacious than warm water, his experiments showed that at 30° F. about one-half the bacilli were removed within one week and practically all within three weeks. At 98° F. practically all were removed in one week, and at the end of two there was no trace. It is generally conceded that about four weeks will be sufficient to remove all danger. The results achieved in the reservoirs of the Boston metropolitan system and others indicate the same thing.

Filtration is used or proposed in a number of water-supply systems in addition to storage. This is often more to improve the appearance, taste, and odor of the water than to improve hygienic qualities, though proper filtration does remove many objectionable bacteria as well.

The board is of the opinion that the regulations proposed will prove sufficient to protect the water supply, and will further protect and not be onerous on campers. It is recommended, however, that the permit provide that no further restrictions will be allowed, and that if these regulations are deemed at any time insufficient the city will filter or otherwise protect its water.

3. *The interference with existing trails and the withdrawal of the excellent grazing grounds of the valley floor.*—This will doubtless be a loss to campers. To compensate, however, the city proposes to build the following roads and trails:

1. A road from Hamiltons or Smiths Station to the Hetch Hetchy Valley.
2. A scenic road on north side of Hetch Hetchy Reservoir.

3. A road from Poopenaut Valley to Hog Ranch.
4. A road from Hetch Hetchy Dam to Lake Eleanor and Cherry Valley via McGill Meadows.
5. A trail to Tiltill Valley and Rancheria Mountain.
6. A trail from Tioga Road past Harden Lake to southerly slope of Smiths Peak and to summit of Smiths Peak.
7. A trail to Vernon Lake.

The city will further supply water for camp purposes at the meadow about one-third mile southwest of Hetch Hetchy dam site.

It is difficult to discuss the location and sufficiency of these roads from the data on hand. The only one which would seem difficult to lay out would be the scenic road along this reservoir. There are certain benches which could be used for a considerable length, but there would doubtless be places where almost vertical cliffs would necessarily be cut into or tunneled. By care it is thought that the scenic road could be constructed without injury to the landscape, though it may be necessary to go back of the valley, and also climb to tops of certain hills to accomplish this object. With these roads and trails as proposed connecting with trails leading from the valley, there should be little difficulty in campers and tourists reaching other camping grounds in the vicinity, even though it is admitted that the covering of the valley floor is a distinct loss. Certain modifications will be proffered by the board in discussing terms of permit.

4. *Use of water at present claimed by other districts or companies for irrigation and power.*—The only definite figures for water rights before the board are the 2,350 cubic feet per second for the Turlock-Modesto irrigation district, reserved in the Garfield permit, when there is that much water flowing in the river, and 60 cubic feet per second used by the La Grange Water & Power Co.

The city, in accordance with instructions from the Secretary of the Interior, submitted a statement by Mr. Percy V. Long, city attorney. In his conclusion Mr. Long states that it has been shown to a reasonable degree of certainty that 39,400 miner's inches, equivalent to 985 second-feet of water, reduced to beneficial use, is all that need seriously concern the city. Mr. Long further states that, considering even uncertain and probably invalid claims, the amount to be reserved would amount to but 115,400 inches, or 2,885 second-feet, and that the total discharge of the Tuolumne will provide for this and the city if adequate storage is provided.

Claims for water rights by other parties have been made. These, however, are for the city to consider and cut out, if necessary, and the city appears willing to accept the responsibility.

5. *Legitimate and proper use of water in the reasonable development of irrigation districts tributary to, or which can be made tributary to, the Tuolumne River.*—The irrigable land between the Merced and Tuolumne Rivers and between the Tuolumne and the Stanislaus will be first considered, excepting the Oakland district, now irrigated from the Stanislaus River. The area of the existing Turlock-Modesto district is 402 square miles. The board estimates that 60 per cent additional could well be added thereto, making a total of 643 square miles. In a recent map issued by the United States Department of Agriculture, in cooperation with the conservation commission of California, the total area of irrigable land in this region is given as about 690 miles. Therefore 643 square miles of land actually to be irrigated within probable districts would seem liberal. It is not claimed, however, that all possible irrigable land is included in this map. There may be, espe-

cially in the foothills, additional land to which water might be well applied.

Based on water being actually supplied to 85 per cent of the 643 square miles—a duty of 2½ feet and losses of 23 per cent—the quantity of water needed is estimated by the board at 1,132,000 acre-feet per year.

The Turlock-Modesto district claims to need for its present district alone 1,042,043 acre-feet. This is stated to be based on 90 per cent of 402 square miles, a duty of 2.75 feet with losses of 3 per cent. These figures are considered extreme and those stated by the board would seem ample.

In the hearing before the Secretary on November 25, much stress was laid on the use of the Tuolumne River water for irrigation at other points of the San Joaquin Valley, especially directly across the San Joaquin River. There has been, as far as known, no exhaustive study made of the irrigable lands of the San Joaquin Valley and the conservation and use of all available water.

The San Joaquin Valley is relatively less well provided with water than the Sacramento Valley, both as to rainfall and as to run-off of rivers. The demands of the valley for complete irrigation are in excess of the water available. At times of low water the San Joaquin above the mouth of the Merced is usually practically dry, all the water being taken for irrigation. Very little storage has been attempted up to the present except for power purposes.

There can be no question but that a large portion, if not all, of the flow of the Tuolumne could be used for irrigation if stored. While the cost of placing the water on the land, especially when necessary to be pumped and carried to long distances, may be more burdensome than the land can at present stand, the increase in value will doubtless in the future warrant such expenditures. It seems quite certain that to irrigate the southern part of the San Joaquin Valley would be less expensive from the Tuolumne than from streams farther north such as the Stanislaus, Mokelumne and American. As above stated, no general project has as yet been made for such use of the water of this valley and there are therefore no estimates available.

For the purposes of this report the board, however, assumes the irrigation of the Turlock-Modesto district only, increased as above stated.

The determination of the amount of water flowing in the Tuolumne has been mainly deduced from records at the La Grange Dam, the point of diversion for the Turlock-Modesto district. This was gaged from 1878 to 1884 by the State of California, and by the United States Geological Survey from 1895 to date. Rainfall records at La Grange date from 1878. There are few records for the upper watersheds. The upper Tuolumne has been gaged by the city for only three years. As this is such a short period, the results obtained by applying to other years the same proportion of run-off for upper and low watersheds as is indicated by the three-year record can not be considered conclusive. At the same time this is all the direct evidence available. In order to assist further in the estimation of this important result, the records of the upper and lower Stanislaus, from 1905 to date have been used for comparison. These records are necessarily incomplete, and therefore to that extent unsatisfactory, but would seem sufficient to arrive at general conclusions. On the

calculations made from these records it is estimated that with a storage of 750,000 acre-feet, the necessary 400 M. G. D. can be taken to San Francisco, while usually giving the full reasonable requirements of 640 square miles of the irrigation district. Of this 750,000 acre-feet storage, about 560,000 acre-feet would be necessary for the city to obtain 400 M. G. D. and the remainder for irrigation. Some years the water supply for irrigation would have been short, as for example in 1898, 40 per cent; in 1908, 14 per cent; and in 1912, 14 per cent. With a storage capacity of 900,000 acre-feet there would have been sufficient water for irrigation except in 1898. For the latter year a storage capacity of 1,400,000 acre-feet would have required and would be practically impossible to obtain economically.

To determine the possibilities of storage an investigation has been made of possible reservoir sites in the Tuolumne Basin and the following table deduced therefrom. In the columns headed "utilizable" is given the amount which during the dry years mentioned could be counted on from these reservoirs. This table divides the reservoirs as follows:

1. Those which are on drainage areas tributary to Hetch Hetchy and Cherry Valleys and Lake Eleanor, and which might become available for either a city water supply or for irrigation. These make up over 80 per cent of the total capacity.

2. Those on other tributaries of the Tuolumne, which could not be advantageously used in connection with the city supply now projected by San Francisco.

Tuolumne River reservoir sites.

Site.	Height of dam.	Capacity (acre-feet).		Total capacity.
		Total.	Utilizable 1896–1901.	
On Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds:	*Feet.*			*M. G.*
Hetch Hetchy	325	344,000	344,000	112,000
Kibbie Lake	40	3,300	3,300	1,100
Lake Eleanor	245	265,200	207,200	86,500
Cherry Valley	150	56,800		18,500
Cherry Creek—				
Big Lake	30	2,600	2,600	850
Buck Meadow	30	3,000	3,000	1,000
Emigrant Lake	60	14,300	14,300	4,650
Louise Canyon	100	9,900	9,900	3,200
Huckleberry Lake	100	52,200	19,700	17,000
Falls Creek—				
Vernon Lake	125	47,900	42,700	15,600
Wilmer Lake	115	5,800		1,900
Tilden Lake	120	27,800	8,300	9,100
Tuolumne Meadows	75	43,200	43,200	14,100
Lake Benson	160	53,800	39,400	17,500
Poopenaut Valley	235	52,100	52,100	17,000
Total	.....	981,900	789,700	320,000
Outside Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds:				
Erraras Meadows	40	1,100	All.	370
Bells Meadows	60	6,300	All.	2,100
Coffin Hollow	35	2,200	All.	730
Hulls Meadow	100	8,000	All.	2,600
Dallas and Warner Lake	.....	60,000	All.	19,500
Davis	.....	48,000	All.	15,600
Dickinson	.....	60,000	All.	19,500
Bradfords	.....	40,000	All.	13,000
Rock Creek	.....	5,000	All.	1,600
Total	.....	230,600	230,600	75,000
Grand total	.....	1,212,500	1,020,300	395,000

It is seen from this table that reservoir capacity exists for preserving sufficient flow for both city supply and irrigation except in exceptional years, when irrigation would suffer. Some of the reservoirs it may not be advisable to construct, as that on the Tuolumne Meadows, which meadows should be reserved for campers. Some of the reservoirs are located so high in the mountains that they will not fill except in years of very high rainfall, and should be kept for emergencies. Other reservoir possibilities doubtless exist in the higher

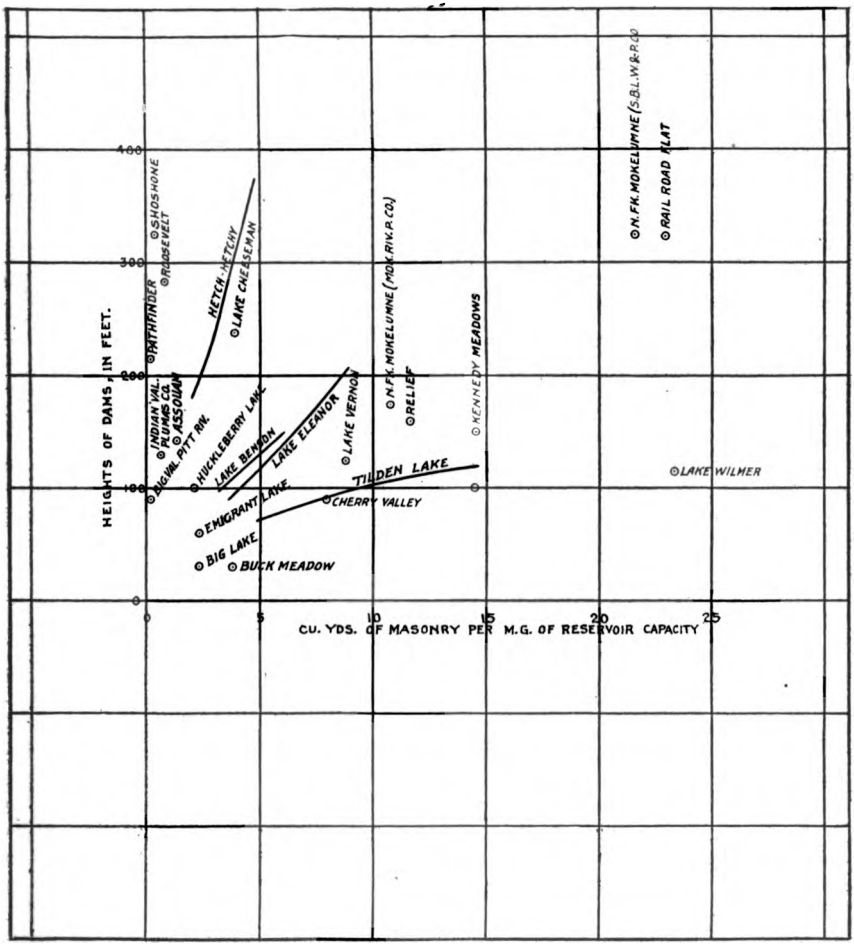

FIG. 1.—Diagram showing quantity of masonry in dams of gravity sections and of various heights, per million gallons of water stored in reservoirs. At some of the sites other types of dams have been used or proposed, but relative economy of storage is not greatly affected.

mountains, too high to have drainage area or too costly to construct. The capacities of the reservoirs below the aqueduct are uncertain, as no exhaustive surveys have been made. These latter would serve only for irrigation purposes, and as the water flowing through the foothills carries silt, they may gradually fill.

The relative cost of the dams as compared to storage possibilities varies greatly. Some are very much more economical than others, as is shown in fig. 1.

In the latest permit asked for by the city it is stated that only the Hetch Hetchy, Lake Eleanor, Cherry Creek, and Poopenaut Valley sites are expected to be used as reservoirs. This would reduce the storage capacity as estimated in the above table by about 175,000 acre-feet.

Even with the reservoirs proposed in the table there would be some years when a considerable quantity of water would go to waste. As far as can be determined from the data available this would be practically entirely from the branches of the Tuolumne below the city reservoirs. It is thought that practically all the run-off of the upper river can be stored, though it may be necessary to construct other reservoirs than those mentioned.

The data as to foothill reservoirs are incomplete. It is possible that reservoirs might be constructed to conserve practically all the flow of the lower rivers.

There can, of course, be no question that it would be to the interest of irrigation to have all the water reserved for that purpose, even if large amounts went to waste in floods.

6. *Reservation of other dam and reservoir sites in the park for the exclusive use of the city.*—It may become desirable that some of the smaller lakes be used as reservoirs, even though not included in the San Francisco project, and in some cases there seems little objection. In the case of Lake Vernon the equalization of the flow of Falls Creek would add to the beauty of Wapama Falls and the Hetch Hetchy Valley during the dry season. Lake Benson, for example, is an economical storage reservoir.

Corporations or communities other than the city of San Francisco might be justly entitled to storage possibilities, and it is thought that these reservoir sites should not be reserved as a whole, but considered individually when proper application is made. In addition, the possibilities of foothill reservoirs should be thoroughly investigated.

PERMIT ASKED FOR.

The city, in its answer to the instructions from the Secretary of the Interior as to why the Garfield permit should not be revoked, submitted instead modifications requested of the Garfield permit. These were submitted January 14, 1913. On February 1 the city authorities requested that paragraph 4 in the permit be modified. This paragraph deals with the method of supplying the claims and needs of the Turlock-Modesto irrigation district. On February 3 the attorneys for the district submitted a new paragraph 4, giving reasons why the one proposed by the city should be modified. On February 8 the city of San Francisco submitted an answer to the substitute of the Turlock-Modesto irrigation district. This document, received February 15, is the last one considered by the board. The permit asked for by the city substituting the modification requested February 1 and the modification asked for by the irrigation company are given below.

The conditions of the permit asked for may be summarized as follows:

(1) Surrender of lands owned by the city in the Yosemite National Park and the Stanislaus National Forest to compensate for camping grounds flooded in Hetch Hetchy Valley.

(2) Statement of sanitary rules necessary to protect purity of water supply.

(3) Authority to develop system according to most feasible and economical manner.
(4) Furnishing stored water to the Turlock-Modesto irrigation district under certain specified conditions.
(5) Authority is given the Secretary of the Interior when requested to direct apportionment of water.
(6) Development of electric power for municipal use and sale to irrigation companies. Lease of power privileges for development by other individuals or corporations.
(7) Statement of time of beginning construction.
(8) Request for permission to make trails and clearings and use material in park for construction purposes.
(9) Request for authority to make use when necessary of other reservoir sites in park, besides Hetch Hetchy, Cherry Creek, and Lake Eleanor, with statement that this will be confined to Poopenaut Valley and small reservoir sites adjacent thereto.
(10) Construction of roads and trails in the park.

The variations from the Garfield permit are substantially as follows:

(*a*) The Garfield permit indicated that the city should compensate by exchange for all land flooded by reservoirs, while the new permit limits the amount to such flooded lands as can be used by campers.
(*b*) Definite rules and regulations are given to protect water supply from contamination.
(*c*) The city is to be allowed to develop in the order deemed best instead of being required to first develop the Lake Eleanor system to full capacity.
(*d*) The city agrees to furnish water from its stored water to the Turlock-Modesto irrigation district under certain conditions, when it can be spared, instead of, as required by Garfield permit, simply not to interfere with natural flow, except when it exceeds 2,350 cubic feet per second.
(*e*) The city does not wish to bind itself to not to ask for additional reservoir sites in the park, and if such should be necessary the city claims that the Garfield permit might prevent it from so doing.
(*f*) The city will be empowered under the new conditions to lease electric power or power privileges to private persons or corporations under proper regulations instead of being limited as by the Garfield permit to municipal purposes and to the Turlock-Modesto irrigation district.
(*g*) Changes in time and order of construction due to changed situation and conditions.
(*h*) Construction of roads and trails not required in Garfield permit.

The permit in full asked for is as follows:

Conditions proposed by San Francisco for modification of the terms of the Garfield permit of May 11, 1908, in the matter of San Francisco's application to the Department of the Interior for reservoir site rights at Hetch Hetchy Valley, Yosemite National Park, Cal.

JANUARY 14, 1913.

1. The city of San Francisco owns all the patented land in the floor of the Hetch Hetchy reservoir site, and sufficient adjacent lands in the Yosemite National Park and the Stanislaus National Forest to equal the remainder of the valley floor so far as camping grounds in that reservoir area are concerned. On the completion of the dam construction operations the city will surrender to the United States such areas outside of the reservoir site and within the national park and adjacent forest reserves as are not needed for gatekeeper's houses, policing and operation, in exchange for the remaining land needed for flooding in the reservoir site to the extent that such exchange is necessary to compensate for the flooding of camping grounds in the Hetch Hetchy Valley, for which authority from Congress will be obtained if necessary.

2. Upon the completion of the Hetch Hetchy Dam or the Lake Eleanor Dam, or of any other dams in the Yosemite National Park, by the city and county of San Francisco, as hereinafter specified, and on the commencement of the use of any reservoirs thereby created by said city and county, or by any other city or cities or metropolitan water district which may join with said city and county of San Francisco in obtaining a common water supply, as a source of water supply for the said city and county, or said other cities, the following rules shall be made effective within the watershed on said reservoir sites so used by said city and county, or other cities:

First. No human excrement, garbage, or other refuse shall be placed in the waters of any reservoir or stream, or within 50 feet thereof.

Second. All sewage from permanent camps and hotels within the watershed shall be filtered by natural percolation through porous earth, or otherwise adequately purified.

Third. It is forbidden to bathe, wash clothes or cooking utensils, to water stock, or in any other way pollute the waters within the limits of the Hetch Hetchy Reservoir or any reservoirs so constructed by the city, or in the streams leading thereto, within 1 mile of said reservoirs; or, with reference to the Hetch Hetchy Reservoir, in the water from the reservoir or waters entering the river between it and the "Early intake" of the aqueduct (as indicated in the report of John R. Freeman, on file in these proceedings), pending the completion of the aqueduct between "Early intake" and the Hetch Hetchy Dam site.

3. The city and county of San Francisco may develop its Hetch Hetchy reservoir site and its Lake Eleanor reservoir site, or any other reservoir site herein described in the Yosemite National Park which may be granted to said city and county, in such order of development as may appear most feasible and proper economically to the officials of the said city and county and the engineers in charge of said work.

4. The city and county of San Francisco, and any other city or cities which may join with said city and county in obtaining a common water supply, will recognize the right of the Modesto irrigation district and the Turlock irrigation district, as now constituted, to receive 2,350 second-feet of the natural daily flow of the Tuolumne River, measured at La Grange Dam, whenever the same can be beneficially used by said districts as now constituted. The said city and county, for itself and its agencies, agrees never to interfere with this right.

Whenever said irrigation districts receive at the La Grange Dam less than 2,350 second-feet of water, and when it is necessary for their beneficial use to receive more water, the said city and county, or other cities, will release, free of charge, out of the natural daily flow of the streams which they have intercepted, so much water as may be necessary for their beneficial use, not exceeding an amount which, with the waters of the Tuolumne and its tributaries, will cause a flow at La Grange Dam of 2,350 second-feet: *Provided, however*, That at such times and seasons as the aggregate daily natural flow of the watershed of the Tuolumne River and its tributaries, measured at La Grange Dam, shall be less than said districts can beneficially use, and less than 2,350 second-feet, then, and in that event, the said city and county, or other cities, shall release, free of charge, the entire natural daily flow of the streams which they have under this permit intercepted.

Whenever said irrigation districts desire water in excess of that to which they are entitled under the foregoing stipulation, guaranty, and agreement, and there is stored in the reservoirs of the said city and county, or other cities, water in excess of the requirements of said city and county, or other cities, and it is safe to do so, having due regard to the occasional occurrence of years of less than average rainfall, the city and county, or other cities, will release to the irrigation districts the whole or any part of said excess for the benefit of said irrigation districts to the amount that may be beneficially used by said irrigation districts, charging therefor a price to said irrigation districts of $2 per acre-foot, measured at the point of discharge from the storage reservoirs constructed by the city and county of San Francisco.

The said city, or association of cities, will, at their own expense, construct such weirs or other suitable structures on sites to be granted, if necessary, by the United States, for accurately measuring the flow in said river at or above La Grange Dam and measuring the natural flow into and out from the reservoirs or intakes of said districts as well as into and out from any reservoirs constructed by said city or cities, or at any other point on the Tuolumne River or its tributaries, and fit same with water-measurement apparatus satisfactory to the hydrographic branch of the United States Interior Department, the apparatus and records to be open to inspection by all interested parties at all times.

The city and county of San Francisco, or such other cities, when they begin the development of the Hetch Hetchy site will undertake and vigorously prosecute to completion a dam at least 200 feet high with a foundation capable of supporting the dam when built to its greatest economic and safe height.

Provided, however, That no prescriptive right or permanent legal right of any nature whatsoever shall ever inure or attach to said districts by the use or otherwise of such excess stored waters which shall thus be released for their benefit and for which said districts shall be charged as hereinbefore provided: *And provided further*, That said districts before calling upon said city, or other cities, for any of this excess storage water, in addition to what they may be entitled to under the foregoing stipulation, must first properly fully develop the storage facilities in their own districts or in the foothills where there are sites economically available or in any portion of the watershed of the Tuolumne River or its tributaries at points between San Francisco's proposed reservoirs or diversions and the districts where such storage facilities are avail-

able and may be economically developed to the fullest economic extent possible. And, further, said districts must at all times so first draw upon their own stored waters to the fullest extent which is possible. And, further, said districts must at all times before calling on said city or other cities for the release of any water, whether the said water be released from excess storage or not, first properly fully develop their said storage facilities to the fullest economic extent possible, and also must first properly fully develop the capacity of their headworks, canals, and aqueducts to the fullest economic extent possible from the said Tuolumne River or its tributaries, or from the La Grange Dam to their said storage reservoirs in order that they might properly conserve and store for their own needs a reserve and excess storage for their own protection in times of drought: *Provided, however*, That the said district shall at all time be required to properly protect their legal rights against any diversion of water from the Tuolumne River or its tributaries by parties other than said city or cities.

And, further, in the event of any dispute between the city and county of San Francisco or other cities and said irrigation districts, concerning the question of the requirements of San Francisco or other cities or the safety of so releasing such excess storage to said irrigation districts, or the requirements of said districts, or as to the full economic development of said irrigation districts of their storage facilities, or as to the full economic development of their said headworks, canals, and aqueducts, or as to the natural daily flow of the waters of the Tuolumne River and its tributaries into the reservoirs of said irrigation districts, or into those of said city or county or other cities, or at any other point on said Tuolumne River or its tributaries, all as in this condition referred to, then such dispute is to be referred for final settlement to the Director of the United States Reclamation Service.

By "the flow," "natural daily flow," "aggregate daily natural flow," and "what is naturally flowing," as these expressions are used in this condition, is meant such flow as on any given day would naturally flow in the Tuolumne River or its tributaries if not intercepted.

5. The city and county of San Francisco or other cities will, upon request, sell, lease, or otherwise dispose of to said Modesto-Turlock irrigation districts for the use of any land owner or owners therein for pumping subsurface water for drainage or irrigation, any excess of electric power which may be generated and which may be so beneficially used by said irrigation districts, such as may not be required for pumping the water supply of said city and county of San Francisco or other cities, and for the actual municipal purposes of the said city and county and the cities associated with it in a water supply, at such price as will actually reimburse the said city and county, city or cities, for developing and maintaining and transmitting the surplus electrical energy thus sold, the price in case of dispute between said city and county or other cities and said irrigation districts, regarding the amount of electric power which may be so required by said city and county, city or cities, for municipal purposes, or by said irrigation districts, then such dispute to be finally settled by the Director of the United States Reclamation Service; and no power plant shall be interposed on the line of flow except by the said city and county or other cities, and for the purposes and under the limitations in this condition No. 5 set forth: *Provided, however*, That no prescriptive or other permanent legal right shall ever inure or attach to said vendees, lessees, or other transferees from said city and county or other cities, by user or otherwise, to the surplus electric power so sold, leased, or otherwise disposed of: *And provided*, That the right of San Francisco and the municipalities associated with it in the Tuolumne water supply to develop electric power for either municipal or commercial use is to be made conditional for 20 years following the completion of the aqueduct from Hetch Hetchy to San Francisco and the furnishing of water from said source to the city and county of San Francisco or other cities, as follows:

The city may and must, within five years from the completion of the aqueduct, install, operate, and maintain apparatus capable of developing at least 10,000 horsepower of electric power for municipal or commercial use; and within 10 years 20,000 horsepower; and within 15 years 30,000 horsepower; and within 20 years 40,000 horsepower; said city and county, or other cities, will agree to use for municipal purposes for the use of their inhabitants, or to sell, lease, or dispose of the same for irrigation, pumping, or other beneficial use at prices approved by the Secretary of the Interior, said price not to be less than will return the actual cost to the city for installation, operation, maintenance, amortization, and interest on cost, including a fair proportion of cost of conduits, lands, and water-supply system; and, further, said city and county, or other cities, must, before using any of said water for the purpose of developing hydroelectric power for municipal or commercial purposes, file such maps, surveys, field notes, or other data as may be required by law, or the rules and regulations of the Department of the Interior, and must conform to any law or rules of said Depart-

ment of the Interior existing and applicable to said subject of development of said hydroelectric power for municipal or commercial purposes.

For all other power capable of being developed along the conduit system of said city and county, or other cities, on which the said city and county, or other cities, do not desire to install pressure pipes, water pipes, transmission lines, etc., for developing the power, the said city and county, or other cities, shall have the privilege of leasing the right to use such power as may be developed at such points on a rental basis, taking into consideration the cost of land and of the physical structures, including conduits and dams necessary to lead the water to the lessees for power development purposes, and, further, that such rentals will not be less than will return the actual cost to said city and county, or other cities, for installation, operation, maintenance, amortization, and interest, the cost including a fair proportion of cost of such lands, physical structures, conduits, or dams; and, further, in the event of any dispute between said city and county, or other cities, and any person who may desire to so lease such right for the use of said power, as to the possibility of so developing such power, or as to the rental charge which should be so made as aforesaid, then such dispute to be submitted to the Secretary of the Interior for final settlement: *Provided, however,* That in case there is at any time any lawfully constituted body, other than officials of said city and county, or other cities, under the law of California, such as the State railroad commission of said State, or any other commission, officer, or board which, under the law of California, has power to fix any rates for the sale, leasing, or disposing of electric power for irrigation, pumping, municipal, commercial, or other beneficial use, or which may have power to determine the terms upon which such electric power may be leased, as above in this condition referred to, then said rates to be so charged by said city and county, or other cities, or said leasing arrangement to be made by said city and county, or other cities, as above in this condition set forth, is to be determined by such commission, board, or officer which may, under the law of California, be so authorized: *Provided, however,* That said Modesto-Turlock irrigation districts shall at all times be entitled to purchase electric power at cost, as in this condition is more fully set forth. And, further, the Secretary of the Interior shall at all times reserve the power to compel the said city and county, or other cities, to so lease such right to use any of such undeveloped power to any party or parties upon the terms in this condition described: *Provided, however,* That no prescriptive or other permanent legal right shall ever inure or attach to said lessees, vendees, or transferees from said city and county, or other cities, by user or otherwise, to the electric power so leased, sold, or transferred.

6. The city and county of San Francisco, or such other cities, will agree that the Secretary of the Interior shall, at his discretion, or when called upon by either the said city and county, or other cities, or the districts to do so, direct the apportionment and measurement of the water in accordance with the terms of the preceding clauses of this stipulation.

7. The city and county of San Francisco will, within three years after these modifications of the Garfield permit, commence actual construction of the aqueduct from San Francisco to the "Early intake," and will carry the same to completion with all reasonable diligence, and will likewise, with reasonable diligence, commence and carry to completion the construction of the Hetch Hetchy reservoir, so that said reservoir may be completed to the 200-foot level within five years after the commencement thereof, unless such time as hereinbefore specified shall be extended by the United States Secretary of the Interior for cause shown by the city, or the construction delayed by litigation; and unless the said work is commenced, carried on, and completed within the time as herein specified, all rights granted hereunder shall revert to the Government.

8. Permission is hereby given San Francisco to quarry, take, and use the necessary building materials near the Hetch Hetchy dam site or any other dam site granted it, within the said Yosemite National Park, for construction purposes, and to construct, occupy, and use necessary trails, roads, telephone and telegraph and power transmission lines, and to suitably prepare and occupy rights of way for said power lines, including the cutting and clearing and use of brush and trees for a distance of 100 feet on each side of said power lines; and to lay water pipes, and to set up, maintain, and operate construction plants for construction and camp use. Also permission is given to build the necessary trails and roads between Lake Eleanor and Hetch Hetchy and between Lake Eleanor and the Cherry Valley reservoir site of the said city and county, and also the right to build such trails and roads as may be necessary to take construction materials to the base of operation, and also the right to cut timber and clear brush from the submerged area in the Hetch Hetchy reservoir basin, or in any other reservoir basin in the said Yosemite National Park granted to San Francisco for its use: *Provided, however,* That the city must, prior to the actual construction

of any of the aforesaid trails, roads, etc., file with the Department of the Interior such maps, surveys, etc., as may be required under the law and under the rules and regulations of the Department of the Interior.

9. The city and county of San Francisco or other cities associated with it in the acquisition of a municipal water supply are to have the privilege, in the development of their Hetch Hetchy water project, to make application, as hereinafter described in this condition, for additional reservoir-site privileges in the Yosemite National Park other than those in the Hetch Hetchy Valley and Lake Eleanor; and upon the proper filing of maps and surveys for said reservoir sites, under the law and under the rules and regulations of the Department of the Interior, said city and county or other cities may, if such maps and surveys are approved by the Department of the Interior, proceed with the development of such additional reservoir sites. The additional reservoir sites which may be so applied for and which are located in the Yosemite National Park are one site in the Poopenaut Valley; and, also, if found expedient for safeguarding the purity of the water of any creek entering the Tuolumne River between the Hetch Hetchy Dam and the "Early intake," the said city and county or other cities may construct small dams, reservoirs, or percolation beds thereupon upon the approval of the Department of the Interior.

10. This permit to develop the Hetch Hetchy reservoir site is conditional upon San Francisco's agreeing to construct on the north side of its reservoir site a scenic road above and along the proposed lake, and also leading from said scenic road a trail to the Tiltill Valley and to Rancheria Mountain, and likewise the city will build a branch wagon-road from its main road in the Poopenaut Valley to Portulaca or Hog Ranch and a trail along the southerly slope of Smiths Peak past Harden Lake to a convenient junction with the old Tioga Road, with a good trail from said trail to the summit of Smiths Peak.

The city will further build from the proposed Hetch Hetchy Dam site a good wagon road to Lake Eleanor and Cherry Valley via the McGill meadows and a good trail to Vernon Lake via the Tiltill Valley or some other convenient route. The city will further lay and maintain a water pipe or otherwise provide a good and sufficient water supply for camp purposes at the meadow one-third of a mile, more or less, southwesterly from the Hetch Hetchy Dam site. Also the city will build and maintain a road from the present main highway near Hamiltons or Smiths Station to the Hetch Hetchy Valley, along the canyon side of the Tuolumne River, past the "Early intake," conveniently near to the proposed aqueduct line, and upon the easiest practicable gradients, substantially as set forth in the report of John R. Freeman filed in these proceedings in July and August, 1912.

All of the above trail and road building to be done subject to approval and under the direction of the United States Secretary of the Interior.

MODIFICATION OF PERMIT PROPOSED BY TURLOCK-MODESTO IRRIGATION DISTRICTS.

The modification proposed by the Turlock-Modesto irrigation districts is as follows:

FEBRUARY 3, 1913.

The city and county of San Francisco and any other city or cities which may join with said city and county in obtaining a common water supply will recognize the right of the Modesto irrigation district and the Turlock irrigation district as now constituted to receive so much of the natural daily flow of the Tuolumne River at La Grange Dam within the limits of their respective original filings of appropriation as may be required for their beneficial use. The said city and county or other cities agree never to interfere with this right.

Whenever the said irrigation districts desire water in excess of that to which they are entitled under the foregoing stipulation, guaranty, and agreement, said city and county or other cities shall release to the said irrigation districts from the reservoir or reservoirs of the said city and county or other cities such amounts of water as may be required for the beneficial use of the said irrigation districts, charging therefor such price as will actually reimburse the said city and county or other cities for storing and conserving the said water so released: *Provided, however,* That the said irrigation districts shall in any event pay for a minimum quantity of such stored water, and shall not be entitled to demand or receive more than a maximum quantity of stored water to be so released during any calendar year.

Such minimum and maximum amounts of such stored water to be so released and the price to be paid therefor by the said irrigation districts is to be determined and fixed by the director of the United States Reclamation Service.

The said city and county or other cities will, at their own expense, construct such weirs or other suitable structures on sites to be granted, if necessary, by the United States, for accurately measuring the flow in the said river at or above La Grange Dam, and measuring the flow into and out from the reservoirs or intakes of said districts and into and out from any reservoirs constructed by the city and county or other cities, or at any other point on the Tuolumne River or its tributaries, as requested by the Secretary of the Interior, and fit the same with water-measuring apparatus satisfactory to the hydrographic branch of the United States Interior Department, the apparatus and records to be open to inspection by all interested parties at all times.

The city and county of San Francisco or other cities, when they begin the development of the Hetch Hetchy site, will undertake and vigorously prosecute to completion a dam at least 200 feet high, with a foundation capable of supporting the dam when built to its greatest economic and safe height.

The said irrigation districts, before calling upon the city and county or other cities for any stored water, must first properly fully develop the storage facilities known as the Davis Reservior of the Turlock irrigation district and the Warner-Dallas Reservoir of the Modesto irrigation district to the fullest extent possible without exceeding a cost of $15 per acre-foot storage capacity. And, further, such districts must first draw upon their own stored waters to the fullest extent which is possible.

In the event of any dispute between the city and county of San Francisco or other cities and the said irrigation districts concerning the requirements of said irrigation districts or as to the full economic development by said irrigation districts of their storage facilities or as to the natural daily flow of the waters of the Tuolumne River and its tributaries into the intakes and reservoirs of said irrigation districts or into those of the said city and county or other cities, or at any other point on the said Tuolumne River or its tributaries, then such dispute is to be referred for final settlement to the director of the United States Reclamation Service.

By "the flow" and "natural daily flow" as these expressions are used in this condition is meant such flow as on any given day would flow in the Tuolumne River or its tributaries if not intercepted by the city and county of San Francisco or other cities.

COMMENTS ON PERMIT.

In case this or a similar permit is granted by the Secretary of the Interior, the board suggests the following changes in the permit as submitted by the city, in addition to those that may be considered necessary by the Interior Department:

In all cases where some official of the Interior Department, such as the Director of the Reclamation Service, is named, the "Secretary of the Interior" should be substituted therefor.

Paragraph 1. It is thought that the city should compensate the United States by exchange for all lands taken by the city for its water supply, instead of only for those of value for camping purposes. Therefore this paragraph should read the same as paragraph 1 in the Garfield permit, with the omission of the word "practical."

Paragraph 2. There should be added thereto:

The cost of the inspection necessary to secure compliance with these rules under the direction of the Secretary of the Interior shall be defrayed by the city of San Francisco and other cities. If at any time the rules are deemed by the cities insufficient to protect the purity of the water supply, then the cities shall install a filtration plant or adopt other measures to guard the purity of the water. No other sanitary rules or restrictions shall ever be demanded by the cities as to the use of the watershed by campers, tourists, hotels, cottages, etc.

Paragraph 3. Does not seem to need any change.

Paragraph 4. This is the paragraph under discussion between the city and the irrigation district involving the legal and other uses of the water by the district. The proposition of the city has not been accepted by the irrigation district, which has submitted a counter proposition. This latter was answered by the city in communication received by the board February 15, 1913, and doubtless, if there were

time, the irrigation district would again answer this last communication.

The proposition by the city is generally as follows: The irrigation district shall develop all economical foothill reservoirs and make full use of same. When the water can be beneficially used the city shall, without cost to the district, release water sufficient to make a flow of 2,350 second-feet, when it is calculated that amount would naturally flow over La Grange Dam, and an equivalent to the natural flow of the river when it is less than 2,350 second-feet. In addition, the city shall, when the water can reasonably be spared from municipal use, release such additional water as can be beneficially used at a cost of $2 per acre-foot. The Secretary of the Interior is to be given authority to make the necessary decisions.

The Turlock-Modesto irrigation district, in its counter proposition, claims that the responsibility for insufficiency of water for irrigation needs should be borne by the city and not by the district; that the district should always be permitted to obtain, by payment, additional stored water; that the needs of the land are such that it must have water at the time the river is low, and when, according to the city's proposition, water would be given only when it could reasonably be spared by the city; that the city, by securing the best and most economical reservoir sites, deprives the district of the ability to store water to the best advantage, and it is the city's duty to see that there is always sufficient water for irrigation, as well as for municipal supply. The district proposes that there shall be fixed a minimum and a maximum supply to be taken by the district. The district claims that the proposed price of $2 per acre-foot is too high, and that the price to be paid should be based on the actual cost of storing and conserving the water. The district further claims that its legal rights to water should not be limited to 2,350 second-feet, allowed by the Garfield permit, but should include the extent of its original filings.

The district further does not agree to the proposition as to the economical development of foothill reservoirs, and submits in return the proposition of development of the two reservoirs now under construction to a cost of not to exceed $15 per acre-foot storage capacity. There are certain other minor changes proposed.

The city in its communication of February 8 discusses these proposed modifications in detail and adheres to its original proposition.

The board is of the opinion that the proposition of the city is a reasonable one. It believes, however, that it is not desirable to have the price of water fixed definitely, but that it should be sold to the irrigation district "at a price which will reimburse the city or cities for the actual cost of storing and furnishing this water," to be determined by the Secretary of the Interior. It would be practically impossible for the city to agree to furnish, regardless of conditions, a certain amount of stored water during the low-water season, as it might deprive the city of water needed absolutely for municipal purposes.

The board believes that the irrigation district should, as suggested by the city, take necessary steps to protect its claimed legal rights. The modification proposed by the irrigation district would apparently throw the burden of this on the city.

There is danger, of course, that the development of storage reservoirs proposed by the city will not prove sufficient to furnish water to the district at all times during the low-water season, and that the proposition to furnish water would mean little, as the water could not always be spared. It is believed, however, that the authority vested in the Secretary of the Interior will be sufficient to enable him to force the city to act reasonably in that regard and to expedite construction sufficiently to meet reasonable requirements of the irrigation district. The suggested economical development of foothill reservoirs is a somewhat difficult question to handle, but no better method is known than that of having the Secretary of the Interior make the necessary divisions.

In a communication received from the authorities of Stanislaus County dated February 8, 1913, it is requested that the permit issued to the city of San Francisco should contain a clause that none of the water diverted from the river shall be used for irrigation purposes outside of the county of Stanislaus whenever such water is desired for irrigating land within the county. This is intended to apply to land not included in the Turlock-Modesto irrigation district.

The board does not consider this a practicable suggestion and sees no reason why the water of the Tuolumne River should be used exclusively by Stanislaus County.

The omission of paragraph 5 of the Garfield permit seems unobjectionable.

Paragraph 5. It would seem reasonable that the United States Government should be entitled to receive power at cost from the electrical development as well as the irrigation districts, and it is suggested that there be added to the paragraph, "and the United States Government for Government use." In the case of the irrigation districts the use of water when once supplied will become such a necessity that it would seem proper that they should have a prescriptive or legal right to water which has once been furnished them, and it is therefore believed that in the first paragraph of paragraph 5, the last sentence beginning "provided, however, etc.," should be omitted, and at the end of paragraph 5 there should be added, "except to the Turlock-Modesto irrigation district and the United States Government for Government use."

The time of commencing the installation of the electric plant as stated in the third paragraph of paragraph 5 is somewhat indefinite, as the full completion of the aqueduct might be long delayed. It is therefore suggested that instead of the words "completion of the aqueduct" there shall be substituted "the date when water is first delivered through the aqueduct."

In a communication of the county officials of Stanislaus County dated February 6, 1913, it is proposed that this electric power shall be furnished the whole county of Stanislaus at cost. Unless it be decided by the Secretary of the Interior that the water of the Tuolumne River shall be reserved for irrigation other than that of the Turlock-Modesto irrigation district, there seems no good reason why the county outside of the district should receive power on different terms from other users.

The policy of the Department of the Interior as to granting privileges for making use of Government reservations for the development

of power is not known to the board. Any general plan or policy could doubtless be made applicable to this case.

Paragraphs 6 and 7. Do not seem to need any change.

Paragraph 8. Add at the end:

And provided further, That the locations of quarries, roads, trails, telephone and telegraph and power lines, pipe lines, construction plants, camps, etc., located outside of the land granted to the city shall first be approved by the Secretary of the Interior.

Paragraph 9. Appears unobjectionable.

Paragraph 10. If it is considered desirable that the city should further compensate for the valuable privilege granted it within the park, additional roads and trails might be required. Those proposed, however, would seem to be sufficient to facilitate access to camping grounds outside of the Hetch Hetchy Valley and other places withdrawn for the use of the city. The scenic road on the south side of the reservoir will be very difficult to construct, will interfere somewhat with the beauty of the valley, and is not necessary for easy communication.

It is believed, however, that the city should be required to maintain the proposed roads and trails as well as construct them, and also should furnish water at cost to people using the park within a reasonable distance of the reservoir. It is therefore suggested that the following additions be made to paragraph 10:

The city will furnish water at cost to any authorized occupants within 1 mile of the reservoir; and it shall reimburse the United States Government for the actual cost of the maintenance of the above roads and trails in a condition comparable with their condition when constructed.

The question of securing compliance by the city with the conditions of this permit is of great importance. Revocation of a permit of this kind to supply water for municipal purposes would be impracticable. It is not anticipated that the city will ever fail to comply with this permit, but it would seem desirable to have some definite means of insuring compliance, and the following is suggested:

In case of failure of the city of San Francisco and other cities to comply with any conditions of this permit, the Secretary of the Interior is authorized to take possession on behalf of the United States, of any part or parts of the system constructed under this permit, including the electric power plants and transmission lines, outside the Yosemite National Park, and to hold and make use of them as he may deem advisable until the conditions of the permit have in his opinion been fully complied with.

It will be noted that the Department of the Interior is liable in a number of instances to be called upon to make decisions and investigations. This will, of course, involve some expense, which apparently should not be borne by the United States Government. It is therefore suggested that, if there is any legal way to do so, the cost of the work done by the Department of the Interior for the benefit of the cities and of the irrigation districts shall be borne in a proper proportion by them.

COMPARISON OF COST OF VARIOUS PROJECTS.

The costs of these projects are difficult, if not impracticable, to determine with accuracy. Sufficient data are not available and the opinions of engineers as to unit costs vary greatly. For example, Mr. Freeman, basing his estimates on costs in the construction of the Los Angeles aqueduct, assumes for certain tunnels a cost of about

$70 a linear foot. Messrs. Mulholland and Lippincott, who constructed the Los Angeles aqueduct, estimate the cost of the same tunnels at $120 per linear foot. As the cost of the tunnel is nearly half of most of the projects, this would naturally affect the total cost. The engineers vary in their estimates as to size and cost of steel pipe, cost of concrete, difficulties of construction, and consequent contingent expenses to be allowed, etc. While actual estimates of costs, present many difficulties, the comparison of relative costs is easier, as practically all the sources would be affected by the same considerations.

The board, therefore, submits its estimates are relative rather than actual.

In making these estimates the unit costs given by Mr. Freeman in his estimate on the Tuolumne supply are assumed as standards, although they appear to the board to be low. These unit costs are modified to suit the varied conditions in other projects. The aqueducts from the Sierra sources follow the same general route and the relative costs are more easily comparable than with the McCloud and Sacramento River supplies. On the line of the McCloud Aqueduct the geological features of the ground are very different. The construction works are more accessible than in the Sierra projects.

The sizes of tunnels, sizes and thicknesses of pipe, the height and size of dams, and capacities of reservoirs were checked by the board. The cost of operation when such operation was common to all supplies, has not been taken into account. Filtration and special pumping have been considered and capitalized at 4½ per cent.

The value of water rights which are included in the estimates of the board are naturally very indefinite as they have not been settled by competent authority.

The value of water power is also indefinite. This is estimated for and stated separately for the different projects.

One of the main difficulties in computing relative costs of projects lies in the fact that in the various plans, constructions, and hence expenditure would be made at different dates. With the McCloud supply practically the whole expenditure will have to be made to obtain any water. On the Sacramento filtered supply, while the total cost is large the expenditure is gradual. The same holds true more or less with reference to the Sierra supplies.

In the estimates submitted by the city these expenditures have been discounted to 1920, and also carried with compound interest to 1950. In its table the board has discounted to 1914. Interest at 4½ per cent is assumed, the board having been informed by the city attorney that this was the usual rate for long-time city bonds.

The difference between the dates assumed by the board and those assumed by the city for the completion of the separate parts of the various projects, and the consequent difference in dates of discount, is due to changes made by the city since the first estimates were submitted and after the estimates of the board had been completed. This is not considered of importance, as reasonable comparison can be made from the assumed basis.

The times assumed by the board as to when additional supplies will be needed are as follows:

100 M. G. D.	1920
140 M. G. D.	1940
200 M. G. D.	1960
285 M. G. D.	1980
400 M. G. D.	2000

The board submits the following summary of estimates:

Summary of estimates.

Project.	Total capacities and construction costs for successive installations.						Present (1914) value of amounts required for financing projects 4½ per cent compound interest.
	M.G.D.	Cost.	M.G.D.	Cost.	M.G.D.	Cost.	
Hetch Hetchy, including Lake Eleanor	160	$37,501,400	240	$51,412,200	400	$77,367,400	$38,900,000
Eleanor-Cherry-Stanislaus-Mokelumne	160	56,414,700	272	85,354,200	400	99,246,800	57,700,000
American-Cosumnes-Stanislaus-Mokelumne	160	52,606,450	272	85,114,850	400	96,711,700	55,300,000
McCloud Bay Crossing	260	65,505,300	400	71,446,200	.....	.....	57,750,000
McCloud (alternate line) via Dumbarton Point	260	72,072,800	400	84,581,000	.....	.....	63,940,000
Sacramento filtered supply Bay crossing	133⅓	39,404,900	266⅔	74,501,300	400	107,012,200	51,700,000
Sacramento (alternate line) via Dumbarton Point	133⅓	43,385,200	266⅔	82,461,900	400	118,953,000	57,040,000
Yuba River Bay Crossing	164	61,944,000	.....	.....	.....	.....	.....

The estimated water rights included in the above table are as follows:

Hetch Hetchy project (Lake Eleanor and Cherry Creek)	$1,070,000
Eleanor-Cherry-Stanislaus-Mokelumne	6,070,000
Stanislaus-Mokelumne, American-Cosumnes	9,000,000
McCloud	5,000,000
Sacramento	None.
Yuba	4,000,000

The estimate of net value of water-power development, capitalized at 4½ per cent, not included in above table, is—

Hetch Hetchy project, 115,000 horsepower	$45,000,000
Eleanor-Cherry-Stanislaus-Mokelumne, 95,000 horsepower	37,250,000
Stanislaus-Mokelumne, American-Cosumnes, 62,000 horsepower	24,300,000
McCloud	None.
Sacramento	None.
Yuba, 54,600 horsepower	21,300,000

From the above table it is seen that in actual expenditures the cost of the Hetch Hetchy project is about $20,000,000 less than for any of the others proposed except for the McCloud River. If the dates of expenditures are discounted the Hetch Hetchy project is about $20,000,000 cheaper than the McCloud. Moreover, there can be no power development on the McCloud under the proposed plan. If it be necessary to store water to supplement the low-water flow of the Sacramento the cost of the McCloud project will be still larger.

The time of beginning construction will depend largely on the development of the near-by sources. It would not affect the general comparison of costs. Such steps as would assure the legal water rights must doubtless be promptly taken.

CONCLUSIONS.

The board is of the opinion that there are several sources of water supply that could be obtained and used by the city of San Francisco and adjacent communities to supplement the near-by supplies as the necessity develops. From any one of these sources the water is sufficient in quantity and is, or can be made, suitable in quality, while the engineering difficulties are not insurmountable. The determining factor is principally one of cost; in some cases, however, such as the Sacramento, sentiment must be taken into consideration.

The project proposed by the city of San Francisco, known as the Hetch Hetchy project, is about $20,000,000 cheaper than any other feasible project for furnishing an adequate supply. The only exception is the filtered Sacramento project, which in actual cost is about thirty millions greater than the Hetch Hetchy project, but by discounting to 1914 becomes only $13,000,000 greater.

The Hetch Hetchy project has the additional advantage of permitting the development of a greater amount of water power than any other.

The best available sources, outside of the Tuolumne River, appear to be the filtered Sacramento, the McCloud, a combination of the Lake Eleanor-Cherry-Stanislaus and Mokelumne, and a combination of the American-Cosumnes-Stanislaus and Mokelumne. For a smaller supply the Eel River or the Yuba River could be used, but they do not lend themselves economically to combination with other sources, and are therefore to that extent not available.

From the statement of Mr. John R. Freeman, in the hearing beginning November 25, before the Secretary of the Interior, it appears that the city, in case of being denied the Hetch Hetchy, will desire to use the Lake Eleanor-Cherry-Stanislaus-Mokelumne combination. In the report of Mr. Freeman of January 30, 1913, the cost of this project is largely in excess of either the McCloud or the Sacramento River projects.

The board is of the opinion that the use of the Hetch Hetchy Valley as a reservoir site is necessary if the full flow of the upper Tuolumne is to be conserved.

The board further believes that there will be sufficient water if adequately stored and economically used to supply both the reasonable demand of the bay communities and the reasonable needs of the Turlock-Modesto Irrigation District for the remainder of this century.

The Valley of the San Joaquin has less rainfall and less run-off from its rivers than the Valley of the Sacramento. The Tuolumne River could if not used for city supply be used to irrigate a large amount of fertile land, as could almost any river in the Valley of California if means are found economically to store the water.

The board believes that on account of the fertility of the lands under irrigation and their aridness without water the necessity of

preserving all available water in the Valley of California will sooner or later make the demand for the use of Hetch Hetchy as a reservoir practically irresistible. The board does not think that a delay of a few years in transforming the Hetch Hetchy Valley into a reservoir is of importance, and therefore does not think it necessary to require delaying construction of this reservoir until the Lake Eleanor and Cherry sources have been fully developed.

The board believes that the regulations proposed by the city will be found sufficient to protect the waters from pollution, and that these regulations will tend toward the protection of campers and others using the park and will not be onerous upon them. It recommends, however, that the permit to the city require the city to take other means, such as filtration, to purify its water supply if these regulations are ever deemed insufficient.

The construction of reservoirs, especially the Hetch Hetchy, will destroy a few camping grounds in the park. The construction of the proposed trails will, however, render accessible other parts of the park not now readily reached, and the number of camping places within the park is large.

The water situation that will confront the communities around San Francisco Bay if the plan proposed by the city of San Francisco is adopted, may be recapitulated as follows:

Purchase of Spring Valley Water Co., $35,000,000 to $40,000,000.

Further development of this company's system to about half the extent proposed by the company, $10,000,000.

Purchase of water systems of communities outside of San Francisco, no estimate made.

Construction of Tuolumne system as proposed by city of San Francisco, to be extended over about 50 years, $77,000,000.

Against the above expenditures there will be developed 115,000 horsepower having an estimated capitalized net value of $45,000,000.

Finally, the board wishes again to emphasize the fact that it does not present the various estimates given as reliable estimates of the cost of the different projects. Sufficient data are lacking as well as time and funds for making adequate investigations. The board believes, however, that the estimates are sufficient to permit such comparisons as are necessary to be made for judging the relative cost and merits of the different projects.

The report of Mr. H. H. Wadsworth is appended as forming part of this report.

A map is also appended of central and northern California, showing the suggested sources of water supply.

Respectfully submitted.

JOHN BIDDLE,
Colonel, Corps of Engineers.
HARRY TAYLOR,
Lieut. Colonel, Corps of Engineers.
SPENCER COSBY,
Major, Corps of Engineers, Colonel U. S. Army.

REPORT ON INVESTIGATIONS RELATIVE TO WATER SUPPLIES FOR SAN FRANCISCO AND BAY CITIES

TO BOARD OF ENGINEER OFFICERS, U. S. ARMY

COLONEL JOHN BIDDLE, Corps of Engineers, U. S. Army
LIEUT. COLONEL HARRY TAYLOR, Corps of Engineers, U. S. Army
COLONEL SPENCER COSBY, U. S. Army (Major, Corps of Engineers)

ADVISORY TO THE SECRETARY OF THE INTERIOR

IN RE USE OF HETCH HETCHY RESERVOIR SITE

BY H. H. WADSWORTH, Assistant Engineer

DECEMBER, 1912

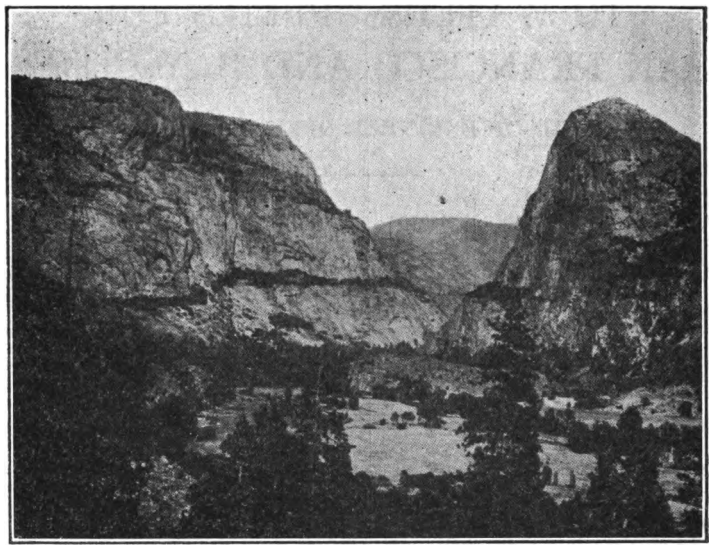

FIG. 2.—View of Hetch Hetchy Valley.

REPORT BY H. H. WADSWORTH.

DEPARTMENT OF THE INTERIOR,
OFFICE BOARD OF ENGINEERS,
SAN FRANCISCO WATER SUPPLY,
San Francisco, Cal., January 17, 1913.

Col. JOHN BIDDLE,
Corps of Engineers, United States Army,
Chairman of Advisory Board, Washington, D. C.

COLONEL: I have the honor to submit herewith my report of investigations of sources of water supply for San Francisco.

This report, except in the matter of cost estimates and suggested combinations of supplies from different sources, is substantially the same as that submitted by me on March 20, 1912, with memoranda of additional data submitted between that date and the close of the hearing before the Secretary of the Interior (Nov. 20–25, 1912), by the city of San Francisco and by the opponents of the grant of the Hetch Hetchy Valley to San Francisco for a reservoir; and with comments on same wherever the deductions then made or conclusions reached are modified by the additional information.

The plan for developing the Tuolumne River supply, especially the conduit system, as given in the report of John R. Freeman, dated July 15, 1912, is so radically different from that previously proposed that cost estimates for that supply and for the suggested supplies (to put them on a comparative basis) have had to be entirely revised.

Following the main report is a supplemental one reviewing the reports and estimates that have been received since the hearing at Washington.

Respectfully submitted.

H. H. WADSWORTH,
Assistant Engineer.

GENERAL STATEMENT.

The order of the Secretary of the Interior, dated May 27, 1910, granting the city of San Francisco a continuance of hearing to June 1, 1911, in the matter of showing why the Hetch Hetchy Valley and reservoir site should not be eliminated from the permit to the city, of date May 11, 1908, contains the following paragraphs:

Said continuance and postponement is granted for the purpose of enabling said city and county of San Francisco to furnish necessary data and information to enable the Department of the Interior to determine whether or not the Lake Eleanor Basin and the watershed contributary, or which may be made contributary thereto, together with all other sources of water supply available to said city, will be adequate for all present and reasonably prospective needs of said city of San Francisco and adjacent bay cities without the inclusion of the Hetch Hetchy Valley as a part of said sources of supply; and whether it is necessary to include said Hetch Hetchy Valley as a source of municipal water supply for said city and county of San Francisco and bay cities.

In granting said postponement and continuance it is understood said city and county of San Francisco will at once proceed, at its own expense and with due diligence to secure and furnish to said advisory board of Army engineers all necessary data upon which to make the determination aforesaid.

Said advisory board of Army engineers is hereby authorized to procure such independent data and information as it may deem necessary or proper to a full and complete determination of the matters committed to said board and the Secretary of the Interior for determination, and that said board may call upon the Geological Survey or other bureaus of the Department of the Interior for such assistance as any such bureau may be able to render in the premises.

It is further understood that said city will, as soon as practicable, submit to said advisory board a full exhibition of its proposed plan of development and utilization of water under said permit, together with estimates of the cost thereof, and also a full statement of all outstanding water rights, both for irrigation, power, and other uses, on the Tuolumne River and Lake Eleanor Basins, and the proposed method of providing for the protection thereof.

In compliance with the obligations imposed by this order, the city of San Francisco has furnished this board maps of surveys of reservoir sites at Hetch Hetchy Valley and at Lakes Vernon, Wilmer, and Tilden on the Tuolumne River watershed, and at Rail Road Flat on South Fork, and at Blue Creek on North Fork of the Mokelumne River; also, map of dam site at Lake Eleanor and map and profile of a suggested canal and tunnel for diverting water from the Rancheria and Falls Creek watersheds to Lake Eleanor. The city has also furnished the records of stream-flow measurements at its gaging stations at Hetch Hetchy and on Eleanor Creek and the city engineer's deductions therefrom. The run-off records for Cherry Creek, rights to which have since been acquired by the city, were furnished by William Ham Hall.

A report on filtered-water supply from the Sacramento and from the San Joaquin, by Allen Hazen, consulting engineer to the city, has also been furnished.

The season of 1910–11 was one of great run-off, which extended well on into the summer. The additional stream-flow records have been of great value in determining the mean ratio of run-off from high positions of a watershed to that from the total watershed above points for which long-time records exist.

The continuance of the hearing beyond the date first set, June 1, 1911, was necessary to permit of the extension of these records through the dry season and for the gathering of much other necessary data, principally as to the availability of reservoirs and their capacities.

The subsequent postponements to March 1, to June 10, and, later, to November 25, 1912, have been necessitated by the inability of the city officials to get their own and their consulting engineers' reports and statements in shape for presentation on an earlier date.

In accordance with an order of the Secretary of the Interior, dated May 28, 1912, there were filed reports by the city of San Francisco as follows:

On June 29:

Report by Allen Hazen, consulting engineer, on the Sacramento River filtration project, containing also a report on the quality of the water of the Tuolumne River.

Report by J. H. Dockweiler, consulting engineer, on the Modesto and Turlock irrigation districts, containing also statements on the same matter by John R. Freeman and by George T. Prince, consulting engineers.

Report on the McCloud River as a source of supply, and papers relating thereto by Marsden Manson, city engineer; C. E. Grunsky and John R. Freeman, consulting engineers; and Percy V. Long, city attorney.

On July 15:

Report by John R. Freeman, consulting engineer, on the proposed use of a portion of the Hetch Hetchy, Eleanor, and Cherry Valleys as reservoirs and appurtenant works for the water supply of San Francisco and neighboring cities.

Report by J. H. Dockweiler, consulting engineer, on sources of water supply, east region of San Francisco Bay.

On August 1:

Statement by Percy V. Long, city attorney, of all outstanding water rights on the Tuolumne River, and the proposed method of providing for the protection thereof.

Report by J. H. Dockweiler, consulting engineer, on condition of water supply of Niles Cone, Alameda County.

Report by J. H. Dockweiler, consulting engineer, on the American Cosumnes project as a source of water supply for San Francisco and adjoining communities.

Report by Cyril Williams, jr., civil and hydraulic engineer, on the water yield of the Hetch Hetchy, Cherry Creek, and Lake Eleanor watersheds.

Report by Cyril Williams, jr., on water supply of the Alameda Creek watershed.

Studies by Marsden Manson, city engineer, of a 60,000,000-gallon daily water supply for San Francisco from Lake Eleanor and Cherry Creek, with power development for municipal purposes.

Report by C. E. Grunsky, consulting engineer, on the Mokelumne River as a source of water supply for San Francisco.

Report by C. E. Grunsky, consulting engineer, on Feather, Yuba, Stanislaus, and Eel Rivers as sources of water supply for San Francisco.

By the opponents of the grant of the Hetch Hetchy Valley to San Francisco Valley for reservoir purposes there have been filed reports and communications as follows:

Review and criticism by George Edwards of reports filed by San Francisco.

Letter from George A. Aldrich re turbidity and discoloration of Tuolumne River water.

Brief by Sierra Club.

Brief of William H. H. Hart.

Reports, propositions, and publications of Sierra Blue Lakes Water & Power Co. re water supply from Mokelumne River.

Reports by Turlock and Modesto irrigation districts.

Report by Mount Shasta Aqueduct Co. on a supply from McCloud River.

Report of Tuolumne River Power & Irrigation Co.

Report of National Park Electric Co.

Two reports by Samuel Storrow and by W. W. Waggoner on water supply from Yuba River.

General report by Spring Valley Water Co. on its system and possible future extensions, including subreports by several engineers and geologists.

Report on water supply of San Francisco by Gen. H. M. Chittenden and A. O. Powell.

Reply to Cyril Williams's report on water supply of the Alameda Creek watershed by George G. Williams.

The City of San Francisco was given from November 1 to November 15 to make reports in rebuttal of reports submitted by the opponents. Such reports have been submitted by engineers making the original reports, as noted above, on the water supply from Alameda Creek and on the needs of the Turlock and Modesto irrigation districts.

Besides the reports mentioned above many communications bearing on the several phases of the investigation have been received.

Under that portion of the order quoted above authorizing the board to procure such independent data and information as it may deem necessary there have been obtained and consulted reports of engineers and promoters of various water-supply and water-power projects. Field inspections and surveys have been made.

During the low-water period of 1910 (September) a trip was made to the Hetch Hetchy and Lake Eleanor region.

The Eel River country was visited in November, 1910. The properties of the Peoples Water Co., now supplying Oakland, Berkeley, and Alameda, have been inspected at various times. The local sources of the Bay Cities Water Co. were visited in January, 1911. The Spring Valley Water Co.'s properties in San Francisco, in San Mateo, Santa Clara, and Alameda Counties and watersheds adjacent to them, were visited in December, 1910, and Spring Valley prop-

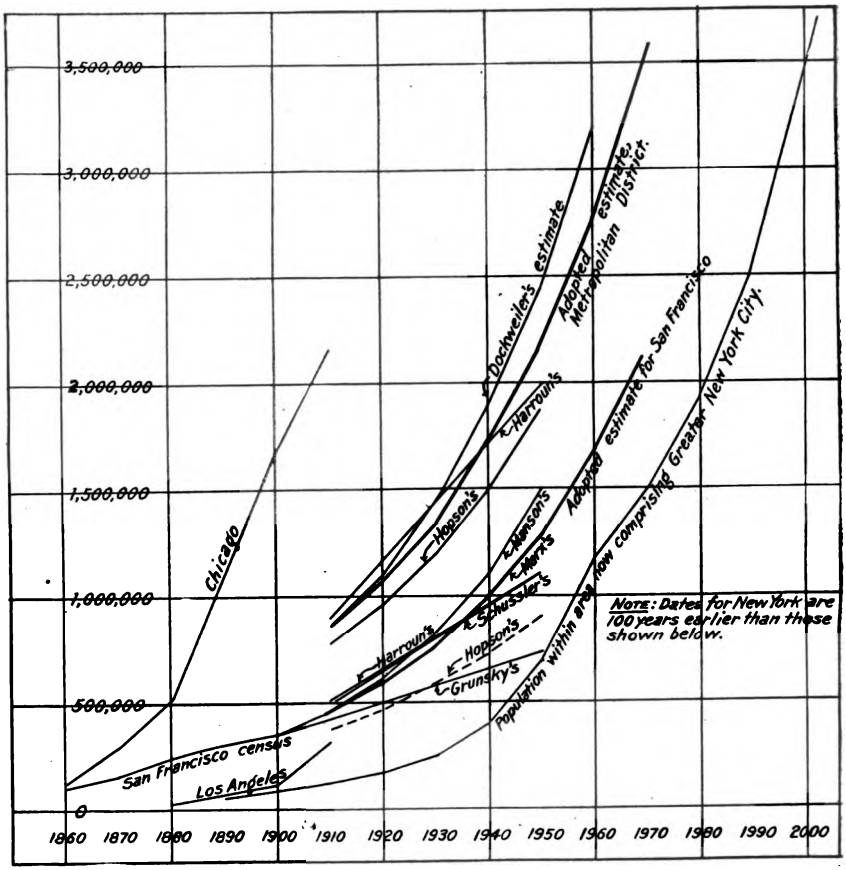

FIG. 3.—Diagram showing increase of population of several cities and estimated future increase of San Francisco and a metropolitan district including the bay cities.

erties again in July, 1911. In June, July, and September, 1911, reconnoissances of the watersheds of the Tuolumne, Stanislaus, Calaveras, Mokelumne, Cosumnes, and American Rivers were made with special reference to the character of the watershed and the possibilities for extensive storage.

In September, 1911, a trip was made to view the McCloud River and its watershed from the vicinity of Mount Shasta to its mouth in the Pitt River and the line of proposed location of an acqueduct from the McCloud River to San Francisco.

In November, 1911, a trip was made to the sites of two proposed low elevation reservoirs on the Yuba River watershed, which form a part of a suggested supply from that stream.

The data secured by observation during these several trips and others previously made over the same and other watersheds those obtained from various sources as described above, together with the data presented at the hearing of May 25, 1910, in Washington, the stream measurement records of the United States Geological Survey, maps of reservoir sites filed with the United States land office, and miscellaneous information gathered from various sources form the material on which this report is based.

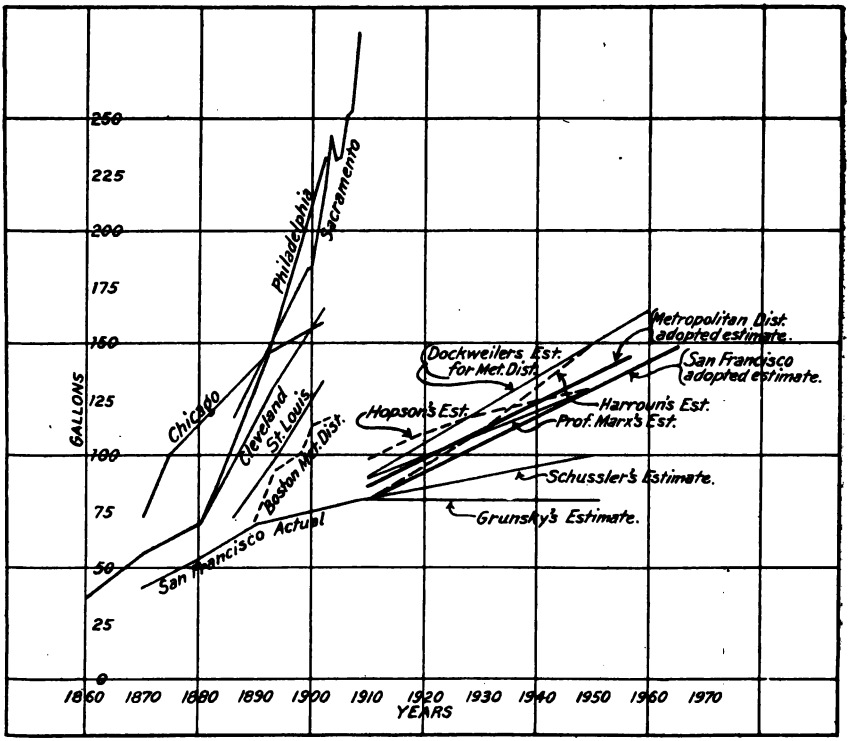

FIG. 4.—Diagram showing per capita consumption of water; actual for several cities and future estimates for San Francisco.

FUTURE NEEDS OF SAN FRANCISCO AND BAY CITIES.

Of the two principal factors on which the future variation in quantity of water consumed by a community depend, viz, increase in population and change in per capita consumption, both may be prognosticated by study of the past record in that community and by comparison with other places. The per capita consumption may be more or less closely regulated by metering the service connections and in other ways preventing waste, but in estimating the possible or probable necessities for many years in the future, liberal factors of safety should be used.

Figs. 3 and 4 show the actual growth of population and the variation in per capita consumption of several American cities and the

estimates by several engineers as to future increase of population and per capita consumption for San Francisco and for the bay region, called on the diagram "Metropolitan district."

Fig. 3 shows an estimated total population for the metropolitan district in—

1934	1,500,000
1946	2,000,000
1955	2,500,000
1963	3,000,000

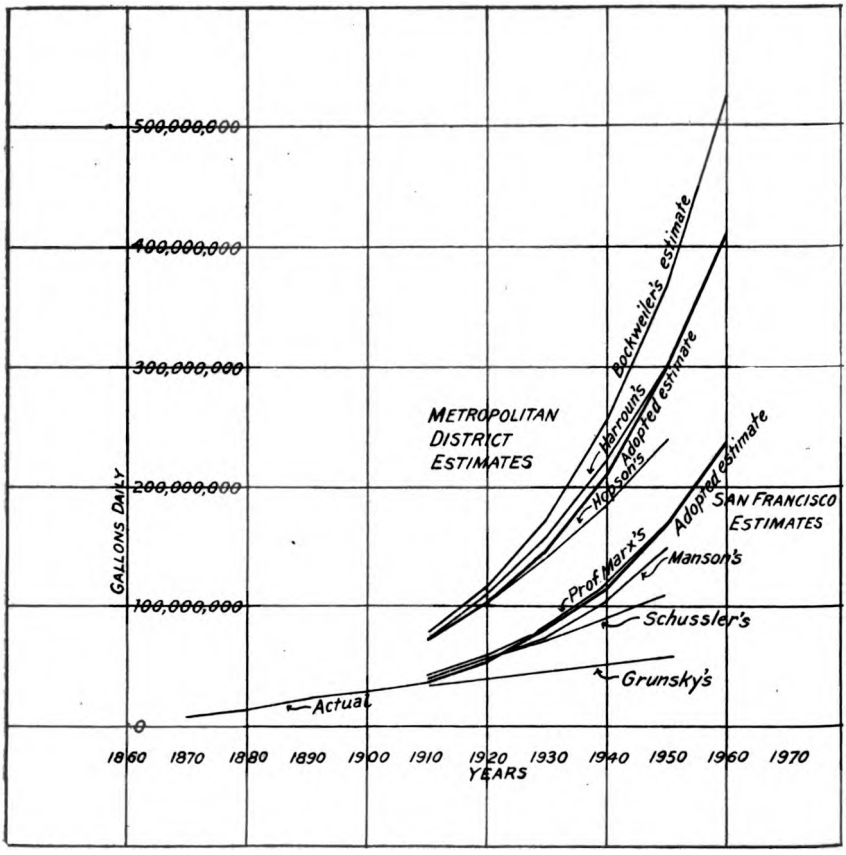

FIG. 5.—Diagram showing estimates of future water consumption. The adopted estimates, shown by heavy lines, are made by combining the estimates (adopted) of figs. 3 and 4.

The "conservative" estimated growth of Greater San Francisco by John R. Freeman, consulting engineer, according to report submitted July 15, 1912, follows:

1939	1,500,000
1956	2,000,000
1975	2,500,000
1995	3,000,000

Fig. 5 shows the total daily water consumption by San Francisco and the metropolitan district resulting from combination of figures

from the two preceding diagrams. It also shows the rate of increase in water supply which, for the purpose of this report, it has been assumed should be provided for.

This shows that for the metropolitan district a supply of 100 M. G. D. will be needed by 1919, 200 M. G. D. by 1938, 300 M. G. D. by 1950, and 400 M. G. D. by 1959.

For San Francisco alone there will be needed 100 M. G. D. in 1936 and 200 M. G. D. in 1955.

Mr. Freeman's report contains an estimate of future demand in the proposed metropolitan water district made by Prof. C. D. Marx, of Stanford University, showing a city consumption by the end of the century of 441 M. G. D., or, including water for irrigation within the district, a total of 540 M. G. D.

The line showing adopted estimate for water consumption by a metropolitan district (fig. 5) would, if extended, indicate a demand of 540 M. G. D. about the year 1970.

LOCAL SUPPLIES.

The quantity of water actually yielded by definite drainage areas on the peninsula and on the east side of San Francisco Bay, as determined by drafts from the reservoirs of the Spring Valley Water Co. and by stream gagings extending over periods of from 20 to 40 years, and including several critical periods, renders it unnecessary to place much dependence on deductions from rainfall records for determining the run-off of the streams.

SPRING VALLEY WATER CO.

Peninsula system.—The proximity of this system to San Francisco, its very large reservoir capacity, capable of extension far beyond that needed to conserve the water from the adjacent areas, and its fairly high precipitation and low rate of evaporation (due to prevailing fogs) make it not only the nucleus of the Spring Valley waterworks but also an essential part of any system for supplying San Francisco which may be acquired in the future. This is especially true of a supply brought from a distant mountain source, the conduits from which may be so damaged by flood, landslide, or earthquake as to result in many days draft on the near-by reservoirs.

There are reports on file in this office by George W. McCoy, M. D., bacteriologist, made under the direction of Dr. Rupert Blue, United States Marine-Hospital Service, showing the excellent quality of the water supplied from this system.

The present and proposed elevations and capacities of the three principal peninsular reservoirs of the Spring Valley Co. are as follows:

Reservoir.	At present.		Proposed.	
	Elevation (feet above sea).	Capacity (million gallons).	Elevation (feet above sea).	Capacity (million gallons).
Crystal Springs	284	19,000	323	45,000
San Andreas	445	5,500	465	9,000
Pilarcitos	695	1,083	695	1,083

It will be noticed that the present capacity of these three reservoirs is sufficient to support a draft of 40 M. G. D. (the present draft) for over 600 days, and that the proposed capacity will support a draft of 200 M. G. D. for 275 days.

The records of the Spring Valley Water Co. show that the yield of water from areas tributary to the Pilarcitos and San Andreas reservoirs was for 12.5 square miles drainage area, during 30 seasons, 1869–1899, 0.664 M. G. D. per square mile; for 13.7 square miles drainage area, during 10 seasons, 1899–1909, 0.855 M. G. D. per square mile. The mean yield for 40 seasons was 0.712 M. G. D. per square mile.

The yielding capacity of Peninsula system, with some proposed modifications, is as follows:

	M. G. D.
Pilarcitos and San Andreas, 13.7 square miles, at 0.712 M. G. D. per square mile.	9. 75
Locks Creek system rebuilt	2. 80
Crystal Springs, 14 square miles (mean annual yield for 32 years)	6. 35
Total	18. 90

Of the areas from which this water is obtained, about 3.8 square miles, which drain into Pilarcitos Lake, and the 2.8 square miles of Locks Creek system, are naturally tributary to Pacific coast streams. The water from these has been diverted by flume and tunnel to the east side of the divide.

It has been proposed, though not recommended for early development, by Mr. H. Schussler, until recently chief engineer and now consulting engineer to the Spring Valley Co., to divert other of the coast streams to the peninsula reservoir system. It was estimated by him that 37 M. G. D. could be obtained from 65 square miles of territory tributary to Pescadero and San Gregorio Creeks, and, by intercepting canals and tunnels, diverted to Crystal Springs Reservoir, via Portola Reservoir (Searsville Lake). The water, about 7 M. G. D., which might be conserved from the natural run-off into the Portola Reservoir, it was proposed to intercept and waste on account of its undesirable quality.

Mr. Samuel Storrow, another consulting engineer of the Spring Valley Co., reported adversely to this project, because of its lack of economy as compared with other schemes.

After visiting this coast stream region in December, 1910, I made rough estimates of the size and lengths of conduits necessary to collect the drainage from these coast streams and carry it to Crystal Springs Reservoir by a conduit and a short tunnel through the low saddle in the ridge west of that reservoir, and found that to conserve 37 M. G. D. from 83 square miles of area the length of conduit per M. G. D. of water secured was almost as great as that for bringing water from the Sierras to the same point, and it would necessarily be very much larger, as its period of service, to anything like its capacity, would be limited to a few weeks each year.

The report submitted by the Spring Valley Water Co. on November 1, 1912, claims a practicable development from the coast streams of 50 M. G. D. To obtain this an additional catchment area is added, a tunnel of 100 M. G. D. capacity through the range is required, and pumps of 50 M. G. D. to lift water from the Pescadero Reservoir are needed.

Alameda Creek system.—The area of the territory tributary to Alameda Creek at the head of the Niles Canyon is 600 square miles. It is a region of considerably less precipitation than that of the peninsula system. The precipitation also varies greatly in different parts of this area. By far the greater portion of the run-off comes from the southerly half of the watershed. In this portion the general elevation is much the higher, the summit of Mount Hamilton being at elevation 4,200 feet. None of the drainage from Mount Diablo, on the north, reaches this catchment area.

At present the Spring Valley Water Co. takes about 15,000,000 gallons daily from the filter gallery in the gravels at Sunol, which are fed by Alameda Creek and its tributaries and from artesian wells at Pleasanton. These wells penetrate into extensive gravel beds overlain by an impervious clay stratum and fed by the drainage from an area of about 425 square miles.

This region can be developed to produce a considerably increased water supply. The Spring Valley Water Co. has acquired title to land for three reservoirs and extensive water rights, and has also increased its holdings in the Pleasanton artesian district. The Bay Cities Water Co. has acquired other water and reservoir rights on the upper portions of the same streams on which Spring Valley claims all the water. However these conflicting claims may be settled, the total quantity of water that may be made available for use will not be materially affected, since so far as this investigation is concerned it makes no difference whether the water is supplied by one or several companies or by the municipalities themselves.

The areas tributary to the three reservoirs proposed by Spring Valley Water Co. and the proposed storage capacities of the reservoirs are as follows:

Reservoir.	Drainage area (square miles).	Proposed capacities (million gallons).	
		Schussler.	Storrow.
Calaveras Reservoir:			
Calaveras Creek and Arroyo Honda	102	30,000	51,000
Alameda Creek	36		
San Antonio Reservoir (part may be diverted to Calaveras Reservoir)	38	8,000	.....
Arroyo Valle Reservoir (may be diverted to Calaveras Reservoir)	100	10,000	.....
Total	276	48,000	.....

As will subsequently be shown, 72,000 M. G. storage is estimated as necessary to conserve the water from the 276 square miles. One-half that storage, or 36,000 M. G., should be sufficient for the 138 square miles which it is proposed to make tributary to the Calaveras Reservoir. To utilize the additional storage proposed by Mr. Storrow, and recently by other Spring Valley engineers, further diversion from other areas is necessary.

Fig. 6 shows by a mass curve (lower curve) the run-off of Alameda Creek at Sunol from records of Spring Valley Water Co.

Much use has been made of mass curves in investigating the relations between storage capacities and draft possibilities of various watersheds, and a word or two in explanation may be desirable. The recorded (or deduced) monthly run-off from a given drainage area

is platted cumulatively to the scales indicated. These scales are, for time, either one-twentieth inch to one month or, more often, one-tenth inch to a month, and for quantity of water, various scales, using sometimes a million gallons, in one instance an inch depth of run-off, but generally an acre-foot as the unit.

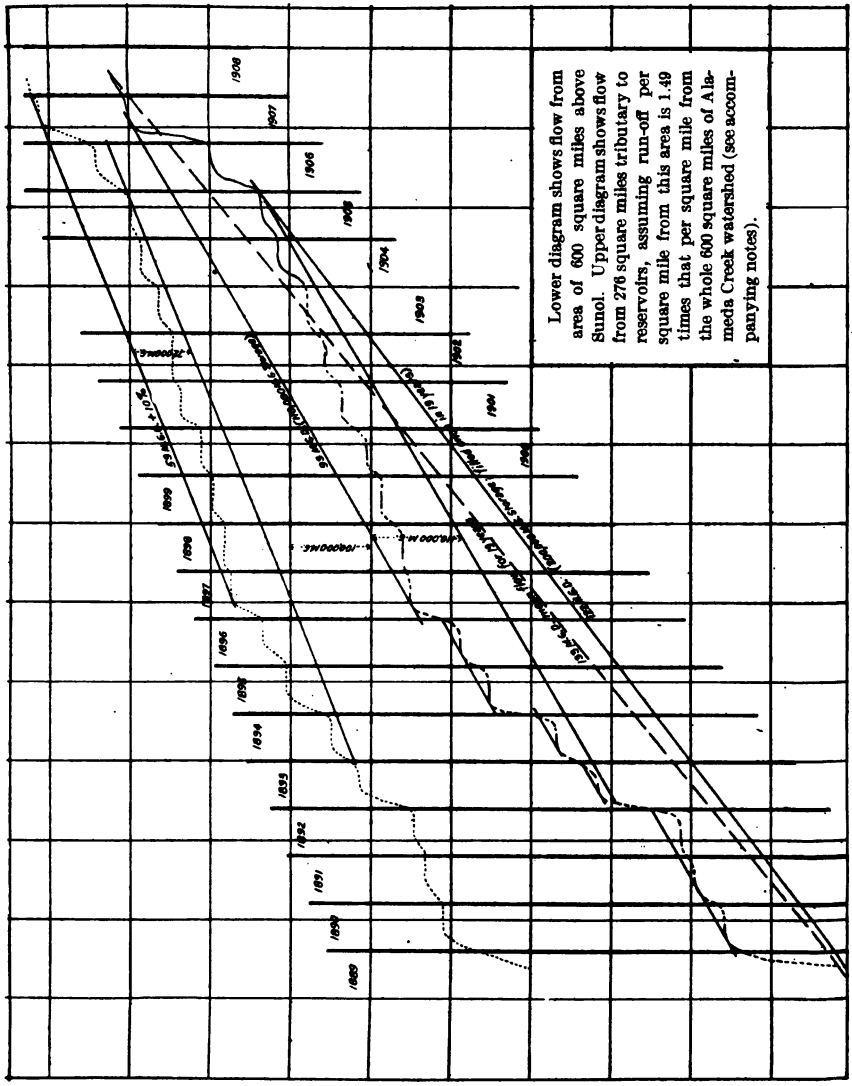

FIG. 6.—Mass diagrams of flow of Alameda Creek.

The difference between lengths of the ordinates to any two points on the curve gives the quantity of run-off between corresponding dates. A straight line connecting two such points shows by its direction the mean run-off for the period covered. The length of the longest intercept of an ordinate between the curve and a straight line connecting

two of its points indicates the storage capacity necessary to maintain the mean flow indicated by the straight line.

In many of the mass diagrams which follow only the water available for storage or diversion is shown, the quantities covered by prior rights having been deducted from the total run-off quantities.

Returning now to the Alameda Creek diagram: The upper curve shows the estimated run-off from the 276 square miles of area tributary to the reservoir sites named.

The figures tabulated in the first seven columns below are from the records of the Spring Valley Water Co. The figures in the fifth column show the seasonal run-off per square mile from the whole 600 square miles of drainage area above Sunol for the period from 1889 to 1908.

Season.	Mean rainfall, Alameda Creek valley (6 stations).	Rainfall at Calaveras.	Ratio between preceding 2 columns.	Run-off per square mile from 600 square-mile area.	Ratio between preceding and succeeding columns.	Run-off per square mile at Calaveras (103 square miles).	Run-off from 276 square miles tributary to 3 reservoirs (see note below).	Cumulative sum of quantities in preceding column.
	Inches.	*Inches.*		*M. G.*		*M. G.*	*M. G.*	*M. G.*
1889–90	38.67	45.54	1.18	260	.....	.....	106,900	106,900
1890–91	18.03	20.23	1.12	54	.....	.....	22,200	129,100
1891–92	20.87	25.24	1.21	31	.....	.....	12,800	141,900
1892–93	31.93	39.20	1.23	171	.....	.....	70,400	212,300
1893–94	26.29	30.81	1.18	91	.....	.....	37,400	249,700
1894–95	31.84	38.63	1.21	136	.....	.....	56,000	305,700
1895–96	22.61	25.82	1.14	62	.....	.....	26,300	332,000
1896–97	26.16	31.20	1.19	105	.....	.....	43,200	375,200
1897–98	12.22	13.37	1.10	14	.....	.....	5,800	381,000
1898–99	18.00	21.98	1.22	41	.....	.....	16,700	397,700
1899–1900	21.87	25.84	1.18	30	.....	.....	12,300	410,000
1900–1901	27.14	30.66	1.13	53	.....	.....	21,800	431,800
1901–2	21.09	23.27	1.10	32	.....	.....	13,200	445,000
1902–3	21.19	24.95	1.18	39	.....	.....	16,000	461,000
1903–4	23.41	27.49	1.17	61	2.68	164	25,000	486,000
1904–5	24.13	28.72	1.19	33	4.85	160	13,500	499,500
1905–6	24.78	24.62	1.00	105	3.00	316	43,400	542,900
1906–7	28.19	35.94	1.27	171	3.10	530	70,400	613,300
1907–8	.....	15.93	.....	35	3.00	105	14,400	627,700

The run-off quantities for the 276 square miles tributary to the three reservoirs are deduced as follows:

Divide the area into three parts as follows:

One hundred and three square miles tributary to Calaveras reservoir site, for which a few run-off figures are given.

One hundred and seventy-three square miles of watershed on Alameda and San Antonio Creeks and Arroyo Valle, the water from which it is proposed to conserve by means of reservoirs, as shown on page 63.

Three hundred and twenty-four square miles, comprising the remainder of the watershed above Sunol, most of which is also tributary to Livermore Valley.

Then, by assuming that the measured run-off from the total area is distributed among the three subareas proportionately to run-off depths for mean seasonal rainfall on those subareas, as determined from a map showing the distribution of rainfall and a run-off curve

as found in a paper by C. E. Grunsky, published in Vol. LXI, Transactions of the American Society of Civil Engineers, we have:

Area.	Mean rainfall.	Mean run-off depth.	Total mean run-off in square mile-inches.
Sq. miles.	*Inches.*	*Inches.*	
103	27	3.5	360.5
173	20	2.0	346.0
324	15	1.0	324.0
600	.....	1.72	1,030.5
276	.....	2.56	706.5

Run-off depth from 276 square miles, or the run-off in M. G. per square mile is $\frac{2.56}{1.72}$ or 1.49 times as much as that from the 600 square miles.

This combined drainage area, 276 square miles, could, according to the diagram, be developed to yield, through a period like that from 1889 to date, about 59,000,000 gallons daily, but would require a storage capacity of 72,000 M. G. If it is not found economical to increase the storage capacity of the three reservoirs mentioned to this extent, there are several excellent sites farther up on the streams now held by the Bay Cities Water Co. that can provide more than enough storage.

The capacity, tributary drainage areas, and safe daily yield of these Bay Cities Water Co.'s reservoirs, as reported by Edwin Duryea, jr., chief engineer, are as follows:

Reservoirs.	Area, square miles.	Storage.	Safe, dependable daily quantity.
		M. G.	*M. G. D.*
Smith Creek	17.9	4,000	5.6
Bonito Creek	5.4	1,400	1.5
Isabel Creek	22.2	7,500	5.9
Arroyo Valle	65.3	10,000	7.6
Total	110.8	22,900	20.6

The yield per square mile is 0.186 M. G. D. with 207 M. G. storage.

In comparison with this, note that the yield per square mile from 276 square miles, as determined above, is 0.213 M. G. D. with 260 M. G. storage.

As to the possible development of a steady and continuous water supply from the remaining 324 square miles of the Alameda Creek drainage system there is a great diversity of opinion. Quite elaborate studies of the underground flow in the Livermore Valley were made by Otto von Geldern, consulting engineer, in connection with suits brought against the Spring Valley Co. on account of alleged lowering of the water plane due to pumping from the Pleasanton artesian

wells. Although some of the results of these investigations tended to show the possibility of a very much greater draft, it is clearly impossible that the aggregate draft through a long period of years could have exceeded the total run-off for the same period. The results of these investigations may be looked upon as the capacity of the gravel beds for filtering water brought from other sources, e. g., the San Joaquin River. (See also below and p. 68.)

A study of the mass diagram of flow of Alameda Creek at Sunol and several draft lines shows the mean flow for 19 years to have been 133 M. G. D., and no amount of storage could have equalized the flow at that figure (less evaporation), for had all the excess water during the term of wet years previous to 1897 been stored, the draft during the succeeding term of dry years, of which the season 1897–8 was the worst, would have exhausted the storage in 1903, and not until 1907 would the actual run-off have caught up with the mean. It would have required a storage capacity of 200,000 M. G. to maintain a draft of 122 M. G. D. (less evaporation loss) throughout the period since 1889, and the reservoirs would have been filled but once during that time.

The greatest possible draft which could have been made on this drainage area (600 square miles) and have left full reservoirs after the winter of great precipitation, 1906–7, is 93 M. G. D. (less evaporation losses from reservoirs). A reservoir capacity of 110,000 M. G. would have been required to support this draft.

It has previously been shown that from the portion of this area where water may be stored in reservoirs a daily draft of 59 M. G. could have been maintained. Allowing 10 per cent of daily draft for evaporation loss (see p. 82), there would have been left 28 M. G. D. = 93 − (59 + 10 per cent of 59) to be maintained from underground flow through the Pleasanton wells.

Whether the gravel beds which underlie extensive areas in Livermore Valley can be relied upon to act as reservoirs to the extent of equalizing this rate of flow without causing damage to agricultural interests by high ground-water level during some seasons and by the excessive lowering of the water plane at other seasons is still an open question.

A recent report by Messrs. William Mulholland and J. B. Lippincott, consulting engineers, on development of ground waters of the Livermore Valley, estimates that with a reservoir in the Arroyo Valle to aid in regulating the run-off from its watershed to the gravels of the Livermore Valley a continuous flow can be developed from the gravel beds "approximating the full mean-water crop of 51.5 M. G. D."

For comparison with the yield of 28 M. G. D., estimated by me above as the upper limit of possible development from the Livermore Valley, the 51.5 M. G. D. (Mulholland and Lippincott estimate) should be decreased to 37 M. G. D., as the difference, 14.5 M. G. D., is approximately the quantity that would have been diverted from Arroyo Valle to Alemeda Creek and Calaveras Reservoir to make up the 59 M. G. D. estimated as a possible conservation of Alameda Creek waters by means of reservoirs.

A report by Cyril Williams, jr., civil and hydraulic engineer, submitted by the city of San Francisco to the board on August 1, 1912, estimates the possible supply from the Livermore Valley at 13.5 M. G. D.

All of the water now taken from the Alameda Creek system of the Spring Valley Water Co. is practically filtered through the natural gravel beds at Sunol and above the Pleasanton Wells. In further developing this system all the water taken could be so filtered, if found desirable, as the waters from the reservoirs could be allowed to flow in natural channels and through the gravel beds to present points of diversion, but by doing this advantage of the elevation of these reservoirs, as head to save pumping, would be lost.

The treatment and disposition of the sewage of the towns of Pleasanton and Livermore require thoughtful consideration in connection with the supply from Pleasanton Wells.

For comparison with 87 M. G. D., estimated limiting capacity of this system, as above, it is noted that Mr. Schussler and Mr. Storrow, consulting engineers of Spring Valley Co., have heretofore estimated 90 and 106 M. G. D., respectively.

The average of the several estimates of safe dependable yield for the Alameda Creek watershed, made by the chief and consulting engineers of the Spring Valley Water Co., submitted November 1, 1912, is 135 M. G. D., though the footnote, under the estimate accredited to Mr. Schussler in the recapitulation of these estimates, together with statements made in the body of his report, indicates that he does not consider his estimate of the mean yield at 130 M. G. D. as a safe dependable one, except by giving the conduit line to Crystal Springs Reservoir a capacity very much greater than that needed for the daily supply, which is not an economical scheme.

To obtain their large estimates of yield, Mr. Hermann and Mr. Anderson not only revise the discharge quantities of Alameda Creek upward, by reason of Prof. Le Conte's experiments, but also revise these quantities still further upward, by reason of proposed reduction of evaporation losses, by assisting the lower gravels under Livermore Valley to receive more of the flood discharge than they now naturally receive.

The report of Cyril Williams, jr., referred to above in connection with the estimate of yield of water from the Livermore Valley, estimates the total supply that may be obtained from the Alameda Creek watersheds at 50 M. G. D. The extreme range of these different estimates—more than 85 M. G. D.—merely represents a corresponding difference in the dates when the development of more distant supplies will be compulsory and is a matter of minor importance so far as the work of this board is concerned.

The new evidence is not sufficient to warrant an increase of my previous estimate of safe dependable yield above 87 (or possibly 90) M. G. D.

For the last 12 or 15 M. G. D. of this yield deep pumping will doubtless be required.

Artesian water from bay-shore gravels.—Around the southerly end of San Francisco Bay is an extensive region in which flowing wells may be made to and actually do yield a large quantity of water. There are said to be places in the bay itself where fishermen at low tide secure fresh water, the volume of it as discharged from springs in the bottom being sufficient to displace the salt water.

The Spring Valley Water Co. has acquired an extensive area of land bordering the bay on the south, and having shown that wells in this area may be extensively drawn upon, hold it as a possible re-

serve supply. These wells may at some time well serve as an emergency supply, but, although there is a considerable literature tending to demonstrate to the contrary, it is not at all conclusively shown that continued draft on an extensive scale would not seriously lower the water plane under the highly cultivated Santa Clara Valley with disastrous results.

A similar condition exists as to possible development of water supply from the Niles Cone; this being the gravel deposit of delta formation radiating from the Niles Canyon through which Alameda Creek flows. It is said that "in consequence of the Sunol and similar developments the water table in the Niles Cone has dropped 30 or 40 feet, and former fine fruit lands have had to be abandoned as such."

The acquirement of land by the Spring Valley Water Co. has done away with much of the contest over injuries to agricultural interests, but this is at the expense of losing population from near-by lands and is of very questionable desirability, as a much smaller area in the Sierras will yield more water, and these Sierra areas are worthless for any other purpose.

An exhaustive report by J. H. Dockweiler, consulting engineer, on conditions of water supply of Niles Cone, filed with the board on August 1, considers both the irrigation needs and the possible water yield of this area. The conclusions of Mr. Dockweiler are to a great extent controverted by the consulting engineers of the Spring Valley Water Co. in reports submitted November 1.

As the Niles region forms a part of the proposed metropolitan water district, its requirements are included in the estimate of future supply needed; so that, although it is at present a matter of vital importance that its local water supply shall not be depleted, or its water table lowered either by excessive pumping or by impounding in reservoirs above Sunol the flood waters of Alameda Creek, on which the maintenance of the water table depends, it is not a matter needing further consideration here.

Coyote River.—The Bay Cities Water Co., in addition to the water rights already mentioned in Alameda Creek in the vicinity of Mount Hamilton, have other rights on Coyote River, which also rises in the vicinity of Mount Hamilton and reaches San Francisco Bay via Santa Clara Valley.

It has been shown in the courts that diversion of these waters directly affects, at its upper end, the water plane under the valley, and such diversion has been enjoined by the courts. Such of the flood waters as may be stored appear to be needed by San Jose and its thickly populated agricultural environs.

PEOPLE'S WATER CO.

This company now supplies the cities of Oakland, Berkeley, and Alameda with about 20 M. G. D., partly from the drainage from the hills immediately back of the towns and partly from wells in the vicinity of Alvarado and others near Richmond.

Very careful investigations made a few years ago under the direction of A. L. Adams, consulting engineer, showed a maximum possible economical conservation from this company's holdings and such adjacent properties as could be advantageously combined with them, about 108 square miles altogether, of about 37 M. G. D. This is a mean annual conservation of 0.6 foot depth of run-off. But little,

if anything, has since been done toward acquiring the necessary additional property or building the necessary structures, so that the present possibilities of expansion are no more than they were, if so much.

SUMMARY OF LOCAL SUPPLIES.

The results as to the quantity of water from local sources which can be conserved for water supply for a metropolitan water district, including San Francisco and the bay cities, may be summarized as follows:

	M. G. D.
Peninsula system of Spring Valley Water Co	19
Alameda Creek system of Spring Valley Water Co.; or Spring Valley Water Co. and Bay Cities Water Co	87
People's Water Co	37
	143
To this might be added such portion of the peninsula coast stream drainage as may prove to be reasonably economical, say	25
Additional pumping from wells	12
Making a total of	180

ADDITIONAL SUPPLY REQUIRED.

Comparing these figures with the diagram (fig. 5) showing the future needs of the district, it appears that if the local supply as given above were first developed, there would be needed in addition 50 M. G. D. in 1942, 100 M. G. D. in 1948, 150 M. G. D. in 1953, 200 M. G. D. in 1957, 250 M. G. D. in 1962, 300 M. G. D. in 1966, 400 M. G. D. in 1975.

If the population should increase as shown by fig. 3 and the per capita consumption, by reason of metering and otherwise reducing waste, should not exceed 100 gallons per day, it would then be necessary to secure from other than local sources 200 M. G. D. by the year 1974, and 400 M. G. D. by about the year 1998.

Omitting from the above estimate of available near-by water supplies, 30 M. G. D., which might quite conceivably be necessary owing to overestimates of practicable yield, in different proportions of the following-named subdivisions of the water-producing districts, and for the reasons given, viz:

People's Water Co.—because of increased difficulty and decreased desirability of securing water from a drainage area in such close proximity to the cities of Oakland and Berkeley;

Livermore Valley—on account of possible impracticability or undesirability to the community at large of using for catchment areas and for subsurface storage extensive districts that might otherwise bear a large population;

Artesian wells in the bay shore gravels—owing to a possible too great lowering of the water tables of agricultural lands;

Diversion of coast-stream drainage—because of doubtful economy the total of local supplies would then be 150 M. G. D. and the date on which an additional 200 M. G. D. would be required would be 1955, according to the water consumption diagram (fig. 5) or 1970, if the per capita consumption were limited to 100 M. G. D. The corresponding dates on which 400 M. G. D. would be required are 1973 and 2000.

If San Francisco alone were considered and of local supplies it etained only the Peninsula reservoir system of Spring Valley Co.,

with the adjacent and tributary catchment area, distant sources would need be developed to produce 200 M. G. D. by 1958 to 1970. It will be noted that the extreme range of dates between which it has been estimated above (under several hypotheses) that an addi-

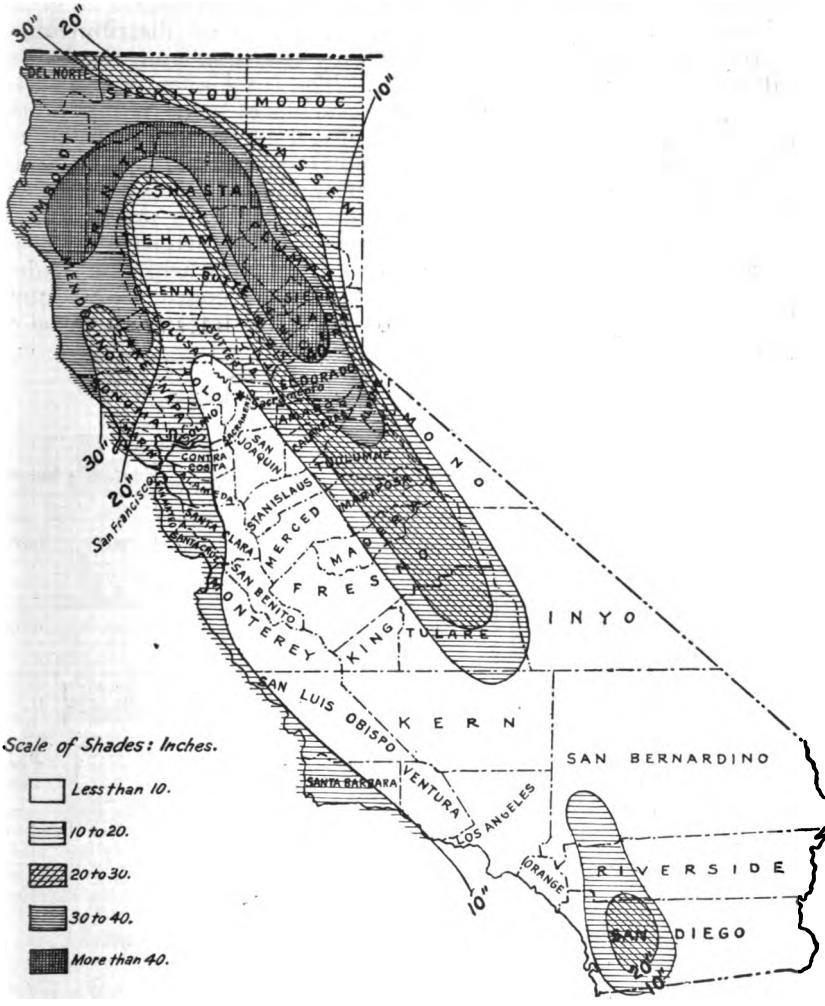

FIG. 7.—Map showing precipitation in California, 1907.

tional supply of 200 M. G. D. will be needed covers a period of 18 years (from 1955 to 1973), and that for the whole proposed metropolitan district 400 M. G. D. will be needed by the end of the present century.

REGIONAL CHARACTERISTICS AFFECTING WATER SUPPLY.

Before proceeding with the consideration of the various possible sources for the required additional water supply there are several characteristics common to all California streams and other elements which affect the general problem to which attention should be given.

Rainfall and run-off.—The characteristic annual distribution of rainfall throughout the State is shown by the map from the United States Weather Bureau report (fig. 7). The total average precipitation each year varies from a very few inches at some points in the Sacramento-San Joaquin Valley to upward of 80 inches at points of 5,000 feet elevation, or over, in the north central part of the State.

The city engineer of San Francisco has prepared an elaborate map, using all data collected to date and showing the very marked effect of altitude on the precipitation even where points considered are a short distance apart only, horizontally. This map, which is made a part of the city's presentation of data to your board, shows quite marked differences in the positions of isohyetal lines from those on previously issued maps.

Precipitation at several points during critical periods.

	San Francisco.	Sacramento.	Auburn.	Georgetown.	Placerville.	La Grange.	Modesto.	Merced.
Record begins	1849	1849	1869	1872	1873	1868	1871	1872
1850-51	7.42	4.71	.....	.....	.....	.....	.....	.....
1862-63	[13.74	11.57	.....	.....	.....	.....	.....	.....
1863-64	10.08]	7.87	.....	.....	.....	.....	.....	.....
1868-69	21.35	[16.64	(?)	.....	.....	18.16	.....	.....
1869-70	19.31	13.57	27.00	.....	.....	12.84	.....	.....
1870-71	14.11	8.47]	17.51	.....	.....	10.46	.....	.....
1876-77	11.04	*8.96*	*18.24*	40.48	22.67	{ *5.74*]	4.30	{ *3.03*]
1877-78	35.18	24.86	36.13	61.31	37.72	18.90	11.51	11.81
1878-79	24.44	17.85	34.94	60.96	38.70	11.54]	8.48	5.83]
1886-87	19.04	{{ 13.97	[27.59	[41.32	33.32	{ 11.01]	{{ 5.72	{ 6.20]
1887-88	16.74	{ 11.56	{ 21.68	{ (36.16	32.87	{ 11.52	{ 6.58	{ 7.08
1888-89	23.86	{ 19.95]	{ 26.75]	{ 36.79]	35.73	14.43]	{ 7.61]	7.80]
1897-98	{{ *9.58*]	10.50	20.36	*31.90*	{{ *21.81*]	10.57	*3.87*	5.76
1898-99	{ 16.87	15.06	29.80	46.70	{ 32.06	12.83	9.35	7.82
1899-1900	18.47]	20.22	37.29	55.67	41.57]	(?)	11.91	11.25
Mean	22.85	19.74	35.50	57.80	43.40	16.55	10.65	10.77
Minimum season	7.42	4.71	17.51	31.90	21.81	5.74	3.87	3.03
Per cent of mean annual	32	29	49	55	50	35	36	28
Minimum mean, two seasons	11.91	9.72	24.21	36.47	26.93	11.26	6.15	6.64
Per cent of mean annual	52	49	68	63	62	68	58	62
Minimum mean, three seasons	14.91	12.89	25.34	38.09	31.81	12.06	6.64	6.89
Per cent of mean annual	65	65	71	66	74	73	62	63

For the period from 1872 to date (for which there are records for all stations):
The mimimum rainfall for a single season is indicated by italic.
The annual rainfall for two consecutive years, the sum of which gives a minimum aggregate, is indicated by braces.
The annual rainfall for three consecutive years, the sum of which gives a minimum aggregate, is indicated by braces.
Other three-year periods for which the aggregate does not exceed the minimum by more than 1 inch are indicated by black type.
For the period between 1849 and 1872 the minimum rainfalls, when less than for the period since 1872, are indicated by brackets.

The relative distribution of rainfall through the year and the great variation from year to year is well shown by the diagrams of rainfall at San Francisco fig. 8 (from the United States Weather Bureau report).

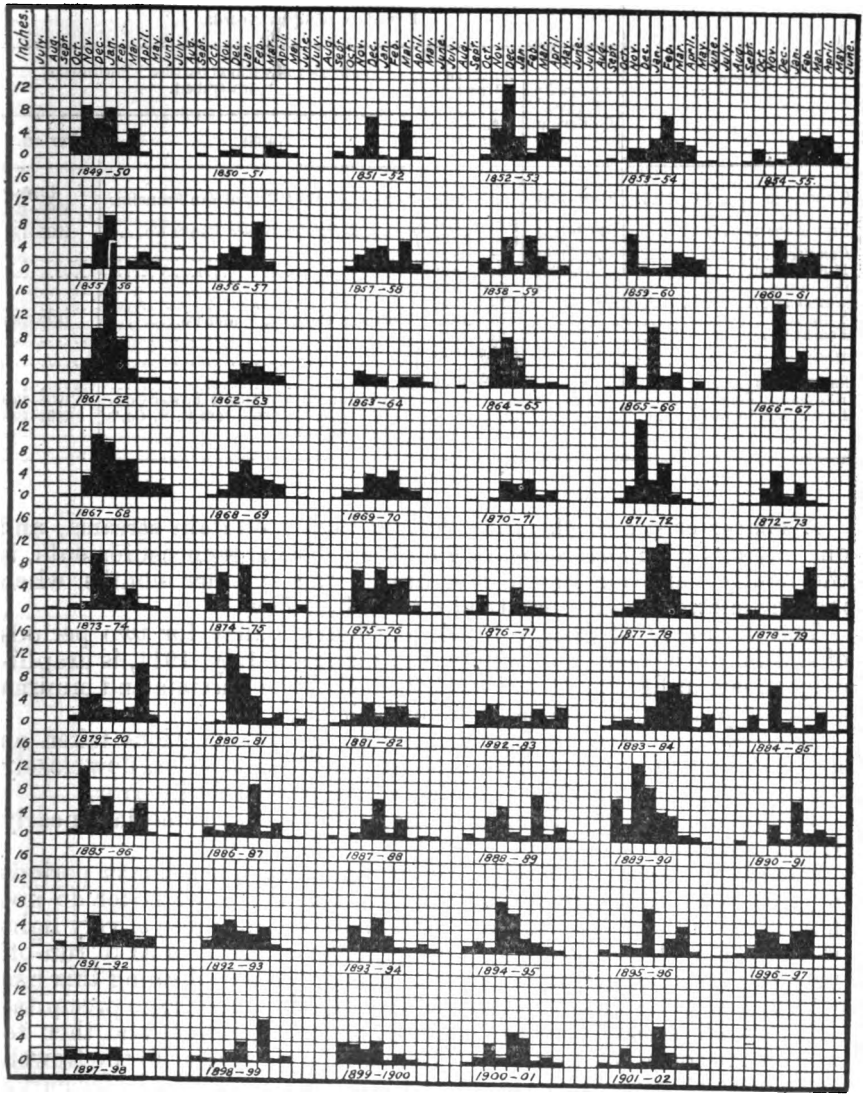

FIG. 8.—Seasonal rainfall at San Francisco, 1849–1902.

Extensive stream gagings were made in California by the State department of engineering through a period of several years, beginning with 1878. Since 1895 the United States Geological Survey has been gaging streams with increasing thoroughness, both as to methods and number of observations, and as to extent of territory covered. Some records of corporations and private parties interested

in the use of water have also been obtained for use in this investigation.

A summary of the records covering the watersheds considered herein is given in the following table:

River.	Periods covered by records.			
	Authority State of California.	Authority United States Geological Survey.	Authority of various parties. Portions of watershed.	
			Name.	Period.
Tuolumne	1878–1884	1895–1912	Wm. Ham Hall, City of San Francisco.	1910–11 1909–1911
Stanislaus	1878–1884	1895–1900 1904–1912	Sierra & San Francisco Power Co.	1905–1911
Calaveras	1878–1884	1907–1912		
Mokelumne	1878–1884	1903–1912		
Cosumnes	[1] 1878–1884	1907–1912		
American		1904–1912		
Yuba		1903–1912	Northern Power & Water Co.	1872–1894
Feather		1902–1912		
McCloud		1902–1908 1911		
Sacramento		1903–1912		
Eel, South Fork			Snow Mountain Water & Power Co.	1905–1909
Lower San Joaquin			C. G. Hyde, deduced from S. P. Co.'s gage heights.	1894–1910

[1] Estimated.

A characteristic of the run-off from high mountain streams, and one having an important bearing on their discharge measurements, is the hourly variation in the flow during the summer months, when melting snows produce practically the whole flow.

The discharge of Cherry Creek at Cherry Valley for two periods of several days each, both within the month of July, 1911, is graphically shown in fig. 9. It will be noticed that the maxima and minima occur at practically the same hour each day.

It is also very evident that results of daily observations taken on such a stream at hours other than those at which the actual flow closely approximated the mean for the day would be greatly in error.

The variation from minimum to maximum was on some days nearly 80 per cent.

Since precipitation records have been kept for much longer periods of years than have stream-flow records, and since the latter do not in most cases cover the extremely critical seasons or those of very light precipitation, it becomes necessary to make deductions as to run-off from the precipitation records. The usual method of doing this has been to first determine as closely as practicable the average precipitation for each season over the drainage area in question and then to take off the corresponding run-off from a diagram similar to the Newell curve or the Grunsky run-off curve for the Sierras. The latter curve is shown in fig. 10.

The determination of the average precipitation over an extended area from that at a few points on or adjacent to the area is practically as difficult a matter as the determination of a fair value for the run-off itself.

A comparison of the records of run-off at several gaging stations with the records of precipitation at stations on the same watersheds,

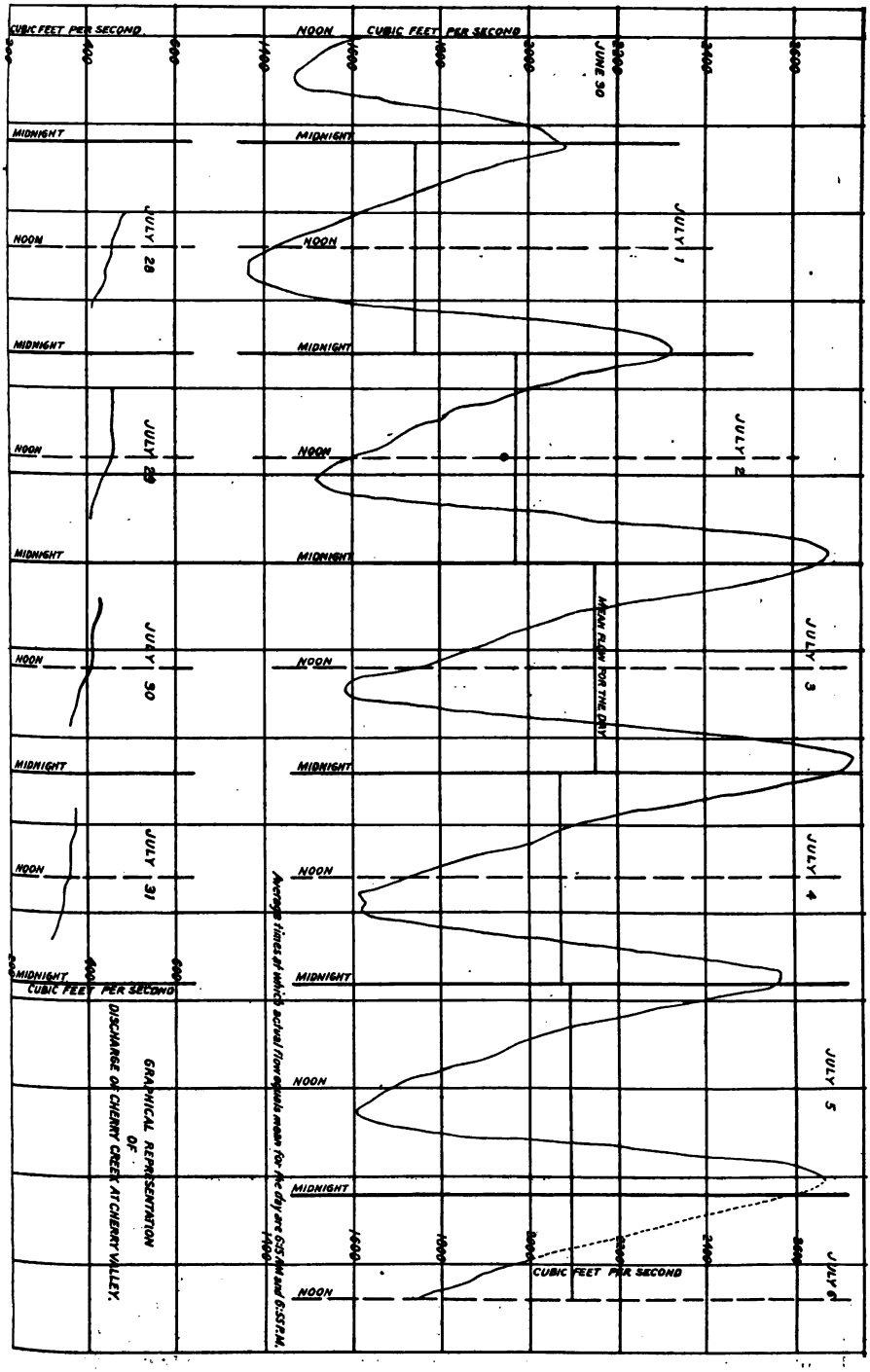

FIG. 9.—Graphical representation of discharge of Cherry Creek at Cherry Valley.

and for which there are also precipitation records running back a number of years, shows relations between the two which are expressed diagrammatically in fig. 10.

Many of the observations conform to the curves shown remarkably well, while, naturally, some isolated ones differ widely from them.

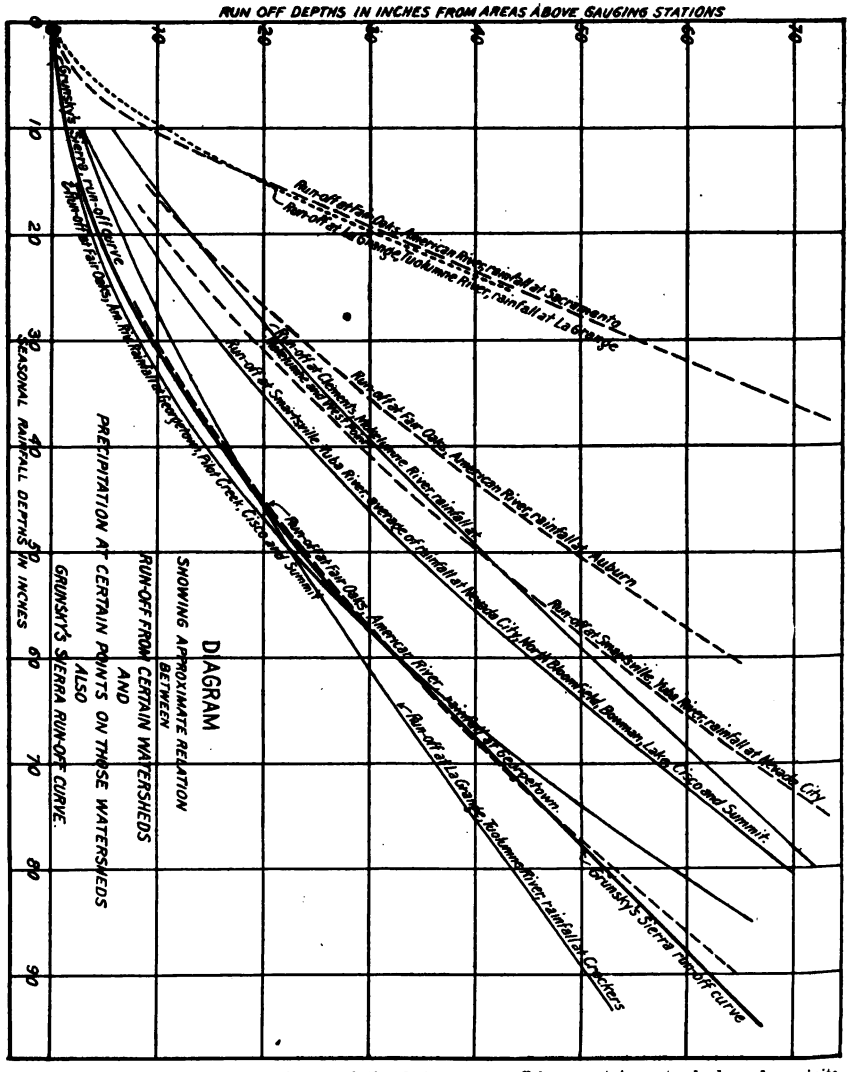

FIG. 10.—Diagram showing approximate relation between run-off from certain watersheds and precipitation at certain points on those watersheds; also Grunsky's Sierra run-off curve.

From these curves the run-off from drainage areas of the Yuba, American, Mokelumne, and Tuolumne Rivers for several periods, including the critical seasons shown on page 72, were taken and mass diagrams were constructed (see figs. 11 and 16). Draft lines showing the possible conservation of water with a given amount of storage in each case were drawn to show the relation existing between different dry periods as to the possibility of water conservation.

Seasonal run-off depths were obtained as follows:
For American River:
1849–1875. Deduced from rainfall record at Sacramento.
1875–1905. Deduced from rainfall record at Sacramento, Auburn, and Georgetown.
1905–1911. From run-off records at Fair Oaks.
For Tuolumne River:
1868–1896. Deduced from record of rainfall of La Grange.
1896–1911. Records of run-off at La Grange.
For Yuba River:
1868–1903. Deduced from record of rainfall at Nevada City.
1903–1911. Records of run-off at Smartsville.

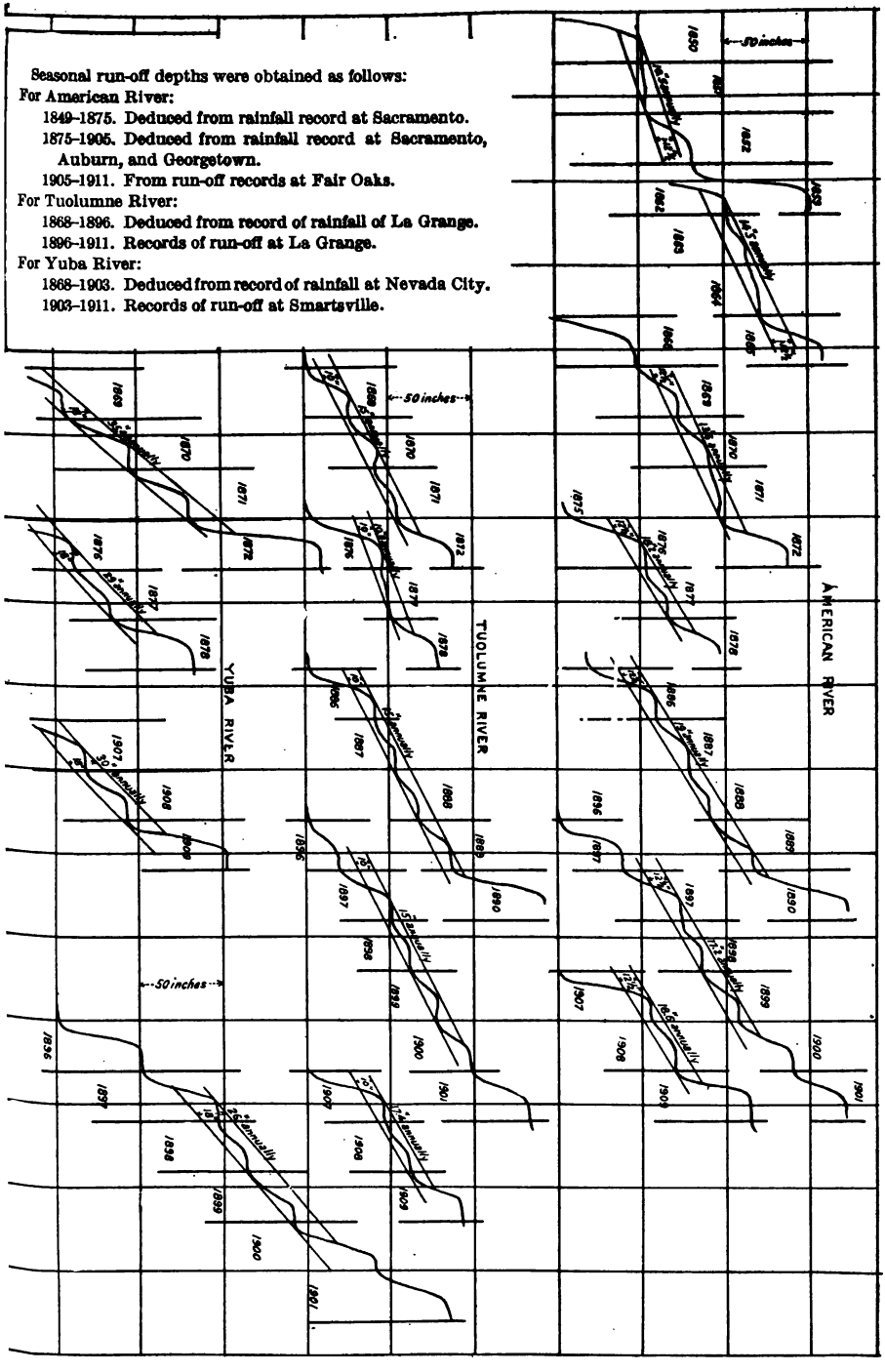

FIG. 11.—Mass diagrams of run-off depths during critical periods; from drainage area of American River above Fair Oaks, from drainage area of Tuolumne River above La Grange; from drainage area of Yuba River above Smartsville.

It should be borne in mind that the question as to whether or not the amount of storage shown on diagram and in following table is attainable, and consequently whether or not the amount shown as conserved can be realized, does not enter into the question now being considered.

This is simply to determine how much more or less critical, as to possible conservation of water, were other dry periods than the one for which there are records of run-off, viz, 1897–1899.

The relation of other periods to this one, for the different watersheds, are shown by percentages in the table, calling 1897–1899 100 per cent:

Period.	Tuolumne storage for 10 inches.		Mokelumne storage for 8.75 inches.		American storage for 12.5 inches.		Yuba storage for 18 inches.	
	Conserved.	Per cent.	Conserved.	Per cent.	Conserved.	Per cent.	Conserved.	Per cent.
	Inches.		*Inches.*		*Inches.*		*Inches.*	
1850–1851	.....	.....	.....	.....	10.5	61	.....	.....
1863–1865	.....	.....	.....	.....	14.5	84	.....	.....
1869–1872	15.0	100	.....	.....	13.6	79	35.4	136
1876–1877	10.8	72	.....	.....	18.2	106	29.0	111
1886–1889	15.0	100	15.48	109	19.0	110	.....	.....
1897–1899	15.0	100	14.20	100	17.2	100	26.0	100
1907–1908	17.4	116	17.75	125	18.6	108	30.0	115

It is seen from the above that, so far as shown by deductions from precipitation records, on only the Tuolumne and American were there worse periods than 1897–1899. It should be noted that for the periods 1850–51 and 1863–1865 figures for the American River only are given, and that these were deduced from precipitation records at Sacramento only. This is, of course, very unsatisfactory, but no other records were available.

The general conclusion from this study is that for the worst probable period a draft of about two-thirds of that possible through the 1897–1899 period, with a given storage capacity, could be maintained. Similarly it may be shown that the drafts shown possible through the 1897–1899 period, with a given storage, could be maintained through the worst probable period by increasing storage 50 per cent. The additional storage reservoirs may be so located that they would be filled only during periods of excessive precipitation and the water so stored withheld for the excessively dry years.

This result is comparable with those obtained by other investigators. For instance, in the case of the proposed Lake Eleanor and Hetch Hetchy water supply a dry period like that of the season 1897–1899 et seq. requires, for 200 M. G. D., storage for about 400 days' supply. For the worst period considered probable by Messrs. Marx and Fitzgerald, consulting engineers for the city (Report of Oct. 23, 1908), storage for 600 days' supply (or 50 per cent greater) was estimated as necessary.

In the reports on various sources of water supply which have been submitted to the board by the consulting engineers for San Francisco no period worse than that succeeding 1897 is recognized, except in the case of the report on the Tuolumne by Cyril Williams. He allows 25 per cent of total storage to remain in reservoirs when greatest depletion occurred, which was in February, 1899. My allowance of water to remain in storage at this time was 33⅓ per cent.

Run-off from high and low areas.—All of the available records of stream flow covering a considerable number of years are at points well down on the streams, where the tributary watershed is large, several hundred square miles in area, partly in the high mountains.

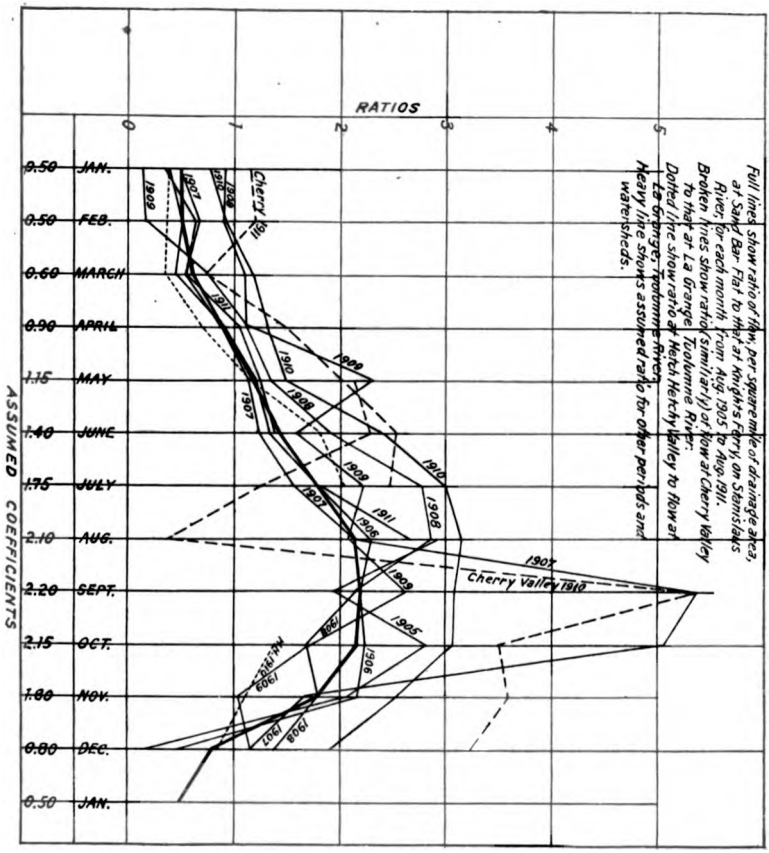

FIG. 12.—Diagram showing ratios of monthly run-off per square mile from high mountain areas to run-off per square mile from large drainage areas. The large drainage areas include with the high mountain areas much lower mountain and foothill country. Full lines show ratio of flow, per square mile of drainage area, at Sand Bar Flat to that at Knights Ferry, on Stanislaus River, for each month from August, 1905, to August, 1911. Broken lines show ratio (similarly) of flow at Cherry Valley to that at La Grange, Tuolumne River. Dotted lines show ratio of Hetch Hetchy Valley to flow at La Grange, Tuolumne River. Heavy line shows assumed ratio for other periods and watersheds.

To determine the corresponding flow from portions of the same areas at high elevations, the ratios of monthly run-off per square mile at Sand Bar Flat to that at Knights Ferry on the Stanislaus River, covering a period of six years, and of that at Hetch Hetchy, Lake Eleanor, and Cherry Valley to that at La Grange on the Tuolumne for periods of from a year to a year and a half were computed and fig. 12 constructed.

This method is the one used by Mr. P. E. Harroun in a presentation made by him at the hearing in Washington on May 25, 1910, and by

Mr. E. G. Hopson in a report to the Secretary of the Interior dated November 23, 1909. The coefficients were modified to fit as nearly as might be the additional observations made.

The total seasonal run-off deduced in this way is sometimes less and sometimes greater than the observed total for the same area. In some cases it is not only about 30 per cent less than the observed run-off from the same area but is actually less than the run-off depths from the much larger area of which the high area under consideration forms a part. The cause for the discrepancy is of course that for the times when the very large coefficients are used the actual run-off is very small, and vice versa.

To correct this error as far as practicable and make the method generally applicable to high mountain areas, a pro rata correction has been made to the monthly run-off quantities so that the seasonal totals will conform to ordinates to a curve similar to the lower curve of fig. 13, corresponding to abscissas, which represent the run-off depth at the low elevation gaging station. This curve, it will be observed, fits very nicely the observations at Sand Bar Flat and Hetch Hetchy Valley.

For smaller areas in the higher portions of a watershed it is apparent from the observations platted that greater proportionate run-off would be justified, such, for instance, as shown by the broken line curve ($y = 4.8 \times 0.7$).

The straight lines marked ($y = 1.5\ x$) and ($y = x$) are shown simply for comparison. The latter indicates the form the curves would take were run-off depths from all parts of the watershed equal.

Evaporation.—The annual evaporation from open-water surfaces varies greatly with the locality and from year to year. Records of the United States Geological Survey show that at Kingsburg, on Kings River, during a four-year period (1881 to 1885) it varied from 2.69 feet to 4.68 feet, the mean being 3.85 feet. At Sweetwater reservoir during a period of 10 years (1889–1899) it varied from 3.75 feet to 5.17 feet. From a tank at Reno, Nev., in 1894 it is given as 3.35 feet. The mean for Clear Lake, Lake County, is given as 32 inches.

Mr. Schussler, of Spring Valley Water Co., states that several years' observation at Crystal Springs reservoir showed evaporation at the rate of one-fourth inch per day for 200 days in the year, or 50 inches per year. For a region with fogs so prevalent as is the peninsula this rate of evaporation as compared with those from the other places mentioned above seems abnormally high. However, it has been given weight in accepting 4 feet as the average annual depth of evaporation from surfaces of Sierra and Coast Range Reservoirs.

It has not been found practicable to modify the mass diagrams of available flow from the various streams, from which draft possibilities for stated reservoir capacities have been estimated, to allow for evaporation from the reservoirs.

In very few cases have the reservoir data been complete enough to make such a procedure possible, even had other data been sufficiently complete to justify it.

On several of the watersheds investigated only the total available storage capacity or the capacity necessary to conserve a given flow of water was known.

A percentage deduction from the draft which the mass diagrams have shown to be possible seems the most rational way of allowing for evaporation.

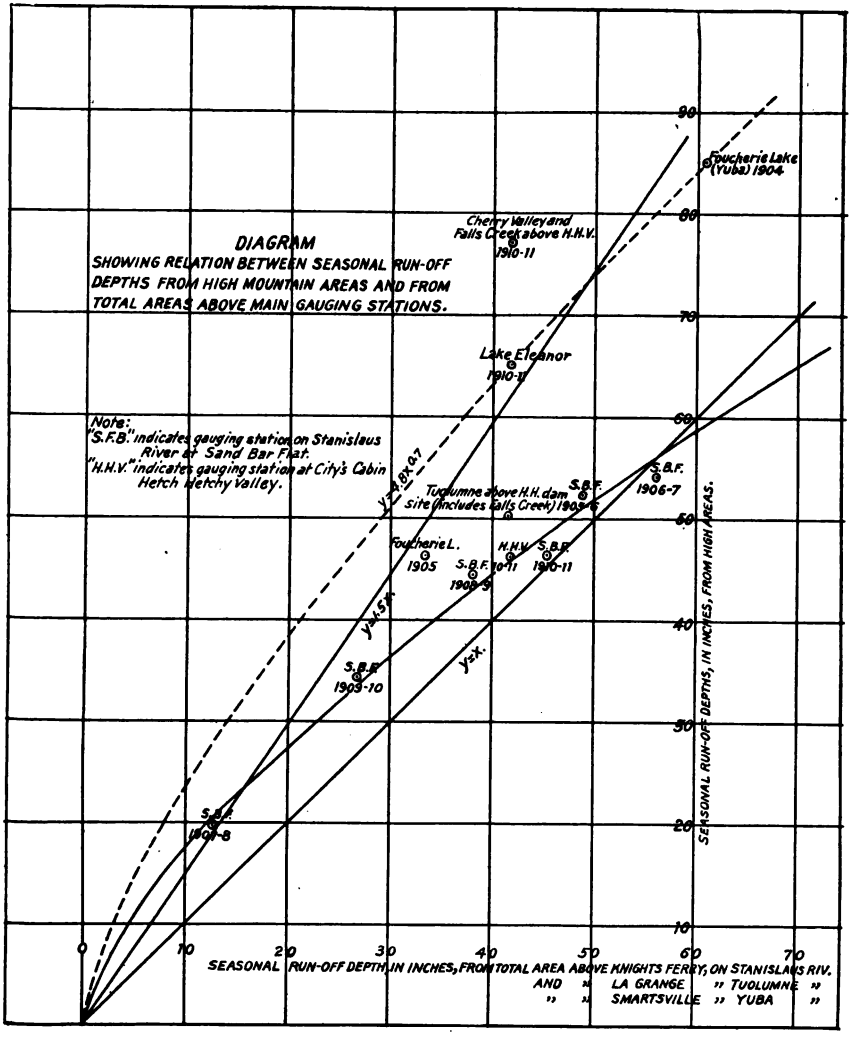

FIG. 13.—Diagram showing relation between seasonal run-off depths from high mountain areas and from total areas above main gaging stations. "S. F. B." indicates gaging station on Stanislaus River of Sand Bar Flat. "H. H. V." indicates gaging station of City's Cabin, Hetch HetchyValley.

The tabulated figures on page 82 show the determination of losses by evaporation from several reservoirs, for which quite full data were available, and a comparison of these losses with the maximum

possible drafts from the reservoirs and tributary watersheds through critical periods. In the case of reservoirs whose areas of water surface, as compared with depth, is large and whose capacity is enough to conserve the flow (or the flow in excess of prior rights) for a term of several years, the evaporation may amount to as much as 10 per cent. In other cases it may not exceed 2 per cent.

Ten per cent has been used in all cases as allowance for losses by evaporation from reservoirs and by evaporation, seepage, and leakage from conduits. For the distant mountain sources the latter loss is likely to be considerable. In the case of nearer sources, such as Alameda Creek, the latter losses will be much less, owing to the shorter conduits and the use of steel pipes; but owing to the very long time that draft must be from storage the evaporation loss alone is very great.

Evaporation losses from reservoirs.

Reservoir.	Reservoir coefficient.	Water in reservoirs.			
		Full—		Lowered to—	
		Depth.	Volume.	Depth.	Volume.
		Feet.	*Acre-feet.*	*Feet.*	*Acre-feet.*
Hetch-Hetchy	0.62	300	352,000	60	23,600
		300	352,000	250	256,600
		300	352,000	299	350,000
		300	352,000	60	23,600
Lake Eleanor		120	90,000	20	2,000
		120	90,000	20	2,000
Rail Road Flat	.42	300	66,000	20	80
		300	66,000	20	80
North Fork of Mokelumne and Blue Creek	.43	300	86,000	20	130
		300	86,000	20	130
Calaveras, Alameda County	.41	160	91,440	30	1,530
		160	91,440	30	1,530

Reservoir.	Period.	Time years, "T."	Maximum possible continuous draft.		Loss by evaporation during time "T."	
			M. G. D.	Totals in time "T."	Acre-feet.	Per cent of draft.
				Acre-feet.		
Hetch-Hetchy	1897–1901	4	264	1,180,000	23,120	2.0
	(1)	0.323	264	95,400	2,450	2.6
	(1)	.00678	264	2,000	54	2.7
	(3)	(2) 4	176	787,000	23,120	3.0
Lake Eleanor	1897–1901	4	54	242,000	16,000	6.6
	(4)	4	36	161,000	16,000	9.9
Rail Road Flat	1897–1899	1.83	66	135,000	2,420	1.8
	(4)	1.83	44	90,000	2,420	2.7
North Fork of Mokelumne at Blue Creek	1897–1899	1.75	139	265,000	3,260	1.2
	(4)	1.75	93	177,000	3,260	1.8
Calaveras, Alameda County	1897–1907	10	[5] 48	537,000	35,170	6.5
	(4)	10	32	358,000	35,170	9.8

[1] Portion of 1897.
[2] 2.5 days.
[3] Worst possible.
[4] Worst.
[5] 48 M. G. D. is the portion of the 59 M. G. D. estimated as possible to conserve from Alameda Creek by reservoirs, which depends on (or can be made to depend on) storage at Calaveras.

POSSIBLE SOURCES OF ADDITIONAL SUPPLY.

The sources of additional supply which have been given more or less consideration, assigning to them the same numbers by which they are designated in the communications from the city engineer of San Francisco, dated June 18 and August 5, 1910, are as follows:

2. Eel River.
3. Putah Creek.
4. Clear Lake and Cache Creek.
5. Sacramento River.
6. Feather River.
7. Yuba River.
8. American River.
9. Lake Tahoe.
10. Mokelumne River.
11. Stanislaus River.
12. Tuolumne River.
13. San Joaquin River.

To this list there has since been added the McCloud River.

Of these, Nos. 3, 4, and 9 were, by action of the board, eliminated from the list so far as further investigation by the city engineer is concerned, for reasons stated by him as follows:

3. Putah Creek.—Inadequacy and lack of available storage.

4. Clear Lake and Cache Creek.—Interference with existing irrigation work and develments and (stated by the city engineer, with references) impurity and pollution of the water.

9. Lake Tahoe.—Remoteness and difficulty of conduit and because its full possibilities are under development by the United States in the Truckee-Carson irrigation project.

These three possible sources have, however, been studied by me and are taken up in their proper order below.

As to the other sources enumerated, the data furnished by the city engineer have been those mentioned in a general way on pages 56 and 57, and more in detail under heads of separate sources investigated.

The investigations made by me as to the well-regulated supply of water that each of these sources may be developed to yield will now be taken up in the same order as given above. These will be followed by estimates of cost for those supplies which alone, or in conjunction with others from adjacent watersheds, may be developed to a capacity of 400 M. G. D.

2. Eel River.—Eel River is a Coast Range stream rising in the northerly part of Lake County, flowing generally north and emptying into the Pacific Ocean about 15 miles south of Humboldt Bay. It is in a region of high precipitation. At a point near Potter Valley the South Fork of Eel River is separated from the South Fork of Russian River by a narrow ridge through which a tunnel has been bored. Below this the Snow Mountain Water & Power Co. has a power plant, under a head of 450 feet, with a capacity of 350 cubic feet per second. The Russian River, into which this water is discharged, flows to the south, toward San Francisco, a distance of over 60 miles.

Above the Snow Mountain Water & Power Co.'s point of diversion on South Fork of Eel River there is a drainage area of 326.5 square miles. Of this, 268 square miles are tributary to an excellent reservoir site at Gravelly Valley, which, with a dam 140 feet high, will store 180,000 acre-feet. A detailed report on the available water supply of the Snow Mountain Water & Power Co. by Messrs. W. R. and

N. A. Eckart, consulting and resident engineer, respectively, has been presented to your board.

A mass diagram showing run-off from watershed above the company's power plant accompanied my preliminary report of April 8, 1911. Actual measurements of discharge cover a period of 5 years. In deducing the run-off from precipitation records for 33 of the 38 years covered by the diagram, Mr. N. A. Eckart used what he calls a "minimum curve," which not only gives results more conservative than the usual "mean curve," but gives a value for the run-off, month by month, instead of annual totals only. The diagram shows that, with the storage capacity given above, this watershed would have yielded a supply of 180 M. G. D. through the most critical seasons occurring within the period of observations, viz, 1877 to date. Mr. Eckart estimates that by taking advantage of large storage capacity at the San Francisco end of the conduit, or on the peninsula, and by giving the conduit a capacity a little in excess of 200 M G. D., the mean supply may be increased to that figure through the most critical periods.

A conduit to carry this water from Potter Valley to San Francisco across the Golden Gate would be about 125 miles long. If, instead of crossing the Golden Gate, its route were via San Pablo Bay and Oakland and thence across San Francisco Bay, it would be 10 miles longer.

Even this greater length of conduit is less than that for any of the Sierra sources. This scheme has also the advantage that the pipe line could be laid much nearer the hydraulic grade line, and thus the weight of steel pipe would be less than for the Sierra schemes, or reenforced concrete pipe could be used over portions of the distance.

The tailrace of the Potter Valley power plant is at about elevation 1,000 feet, giving sufficient head for delivery of water to Crystal Springs Reservoir by gravity.

The crossing of the Golden Gate, where the water is 360 feet deep for the shorter line, or the double crossing of the bay, for the line via Oakland introduces features which, in point of great depth, would be somewhat similar to the tunnel crossing of Hudson River at Storm King by the Catskill Aqueduct. The elements of cost are not comparable with those of the other schemes.

To use the Russian River itself as a conduit and thus save 60 miles of pipe line, as has been suggested, would require a large increase in power over that which could be developed from the water supply itself to deliver the water and would make thorough filtration necessary, so that the scheme would not have advantage over one for using Sacramento or San Joaquin water. The president of the Snow Mountain Water & Power Co. states that he has plans for the utilization of this supply in the Russian River Valley, and has made no proposition to the city of San Francisco regarding its acquirement by the city.

A supply from Eel River could not be advantageously combined with one from other sources. The investigation of this project has not been carried further.

3. Putah Creek.—Putah Creek drains the easterly slope of the Coast Range, south of Clear Lake, and discharges its waters into the Tule lands of Yolo Basin. The watershed above Winters has an area of 805 square miles. As shown by mass diagram (fig. 14), a storage

capacity of 150,000 acre-feet would have been necessary to equalize a flow of 200 M. G. D. through the season of 1907–8, and doubtless 100 per cent greater than that for the dryest seasons.

Surveys have been made of two sites for reservoirs, having an aggregate capacity of nearly 150,000 acre-feet. The drainage area above them is but little more than one-half of that above Winters.

4. Clear Lake and Cache Creek.—Clear Lake is in Lake County. It has an area of about 65 square miles and an elevation of 1,325

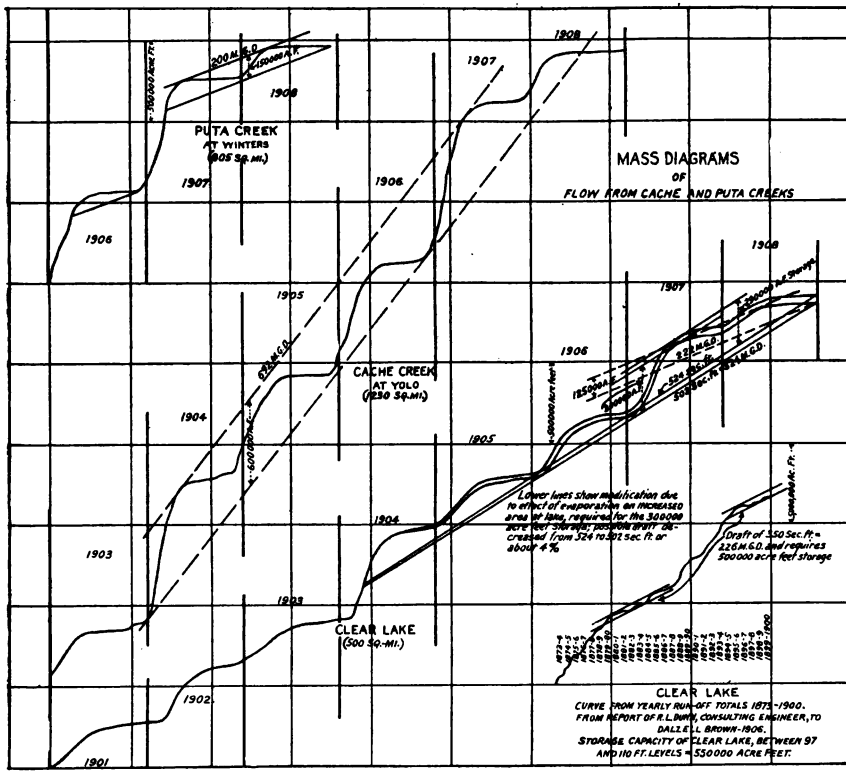

FIG. 14.—Mass diagrams of flow from Cache and Putah Creeks. Clear Lake curve from yearly run-off totals 1873–1900. From report of R. L. Dunn, consulting engineer, to Dalzell Brown, 1906. Storage capacity of Clear Lake, between 97 and 110 foot level, equals 550,000 acre-feet.

feet at mean level. The tributary drainage area is about 500 square miles. Some of the peaks on this watershed reach an altitude of 6,000 feet.

Fig. 14 shows mass diagrams, both of the run-off from the Clear Lake drainage area and for the whole of Cache Creek at Yolo (tributary area, 1,230 square miles) for the periods through which the records have been kept by the United States Geological Survey. There is also shown a mass curve of yearly run-off (1873–1900) from Clear Lake, platted from quantities computed by Russell L. Dunn, consulting

engineer, from lake levels, as given in a report made by him to Mr. Dalzell Brown. This latter diagram illustrates nicely the greatly increased storage required to support a given draft through periods of dry years like 1881, 1882, 1883, and 1897, 1898, and 1899, as compared with those for which stream-flow measurements are available.

Within the proposed limits of regulation of lake levels (greater elevation of lake surface would too greatly increase area of valuable lands that would be flooded) 600,000 acre-feet could be stored. These would permit a draft of more than 200 M. G. D. through the dry periods of 1880–1883 and 1897–1899.

Irrigation projects utilizing these waters are in process of development.

5. Sacramento River.—The principal features of a water supply for San Francisco from the Sacramento River are filtration and pumping.

At Collinsville, at the mouth of the river, the water becomes slightly brackish late in the season during years of light rainfall. At Rio Vista, 13 miles above Collinsville, it is always fresh. It has been suggested that the increasing demand for water for irrigation may in time draw so heavily on the river and lower it to such an extent that the upper limit, within which there may be brackish water in the late summer and fall, may move up well toward Sacramento.

Current meter observations made in August, 1908, at Courtland, 24 miles below Sacramento, gave a discharge of about 7,000 cubic feet per second. The lowest stage of the river that season occurred about a month later, when the gage height was the lowest for many years. The discharge, however, was not less than at the lowest stage reached each year from 1898 to 1902, inclusive. The minimum discharge during this period was about 10 per cent less than in 1908, or probably about 6,000 second-feet. Determinations made from cross sections and slopes gave for the 1909 low-water flow of the Sacramento River, above the mouth of Feather River, more than 5,000 cubic feet per second. The season of 1911–12, being one of extremely light precipitation, it was thought that the record for small run-off would be broken; but although such is the case for most Sierra streams, the discharge of the Sacramento below the mouth of the American did not fall below about 6,300 second-feet.

Under the present regulations of the War Department governing taking water from the river diversion is permitted only when the stage of the river is 2 feet or more above low water. On the upper river, above Monroeville, this stage may be reached in June; but at Sacramento, even during the low-water year of 1908, it did not reach this stage until July 18, or well toward the close of the season of heaviest irrigation as now practiced in the Sacramento Valley. In 1909 the same stage was not reached until August 6.

As an indication of the extent to which the low-water flow may, in the future, be increased by reservoirs in the mountains, attention is called to the Big Meadows Reservoir site in Plumas County, controlled by the Great Western Power Co. This, with a dam 85 feet high, will have a capacity of 450,000 acre-feet, or sufficient to maintain a flow of 2,500 cubic feet per second (the capacity of Big Bend tunnel, through which the power plant is supplied) for 90 days. The minimum flow of Feather River at Oroville since 1901 was in September, 1903, 1,200 second-feet; in 1908 it was 1,250 second-feet. At Big Bend in 1908 it was 960 second-feet.

There are several other favorable sites in northern California for water storage, so that with power development, irrigation, and navigation interests all dependent on a well maintained low-water flow of the streams, and considering also that a considerable percentage of water used for irrigation seeps back into the streams, it does not seem likely that the flow of Sacramento River need be so lowered as to permit sea water to get materially farther up the river than at present. In this connection, see extracts from reports of Col. Mendell and of Prof. C. G. Hyde, page 118.

Water taken from the Sacramento to San Francisco would have to be carried under the San Joaquin, nearly a mile wide in its lower reaches, or across Carquinez Straits by submarine pipes.

It seems, at first glance, more economical to take water for a filtered supply from some of the numerous channels of the lower San Joaquin with the waters of which those of the Sacramento mingle. This will be further considered under project No. 13. The relative advantages of filtered water supplies from the Sacramento and San Joaquin Rivers have been quite thoroughly studied by Mr. Allen Hazen, consulting engineer to the city, whose report has been presented to your board.

Mr. Hazen's report shows that although either the Sacramento or San Joaquin water could be satisfactorily purified by filtration, the Sacramento water is now much softer than the San Joaquin and is not so likely in the future to increase in hardness to so great an extent, owing to its use for irrigation and consequent seepage back to the river.

The Sacramento water contains a much larger percentage of total solids and has a much greater degree of permanent hardness than the water from any of the proposed Sierra catchment areas. It is, consequently, even after filtration, a less desirable supply.

Mr. Hazen suggests several possible routes for conduits to San Francisco. He recommends one starting from an intake at Rio Vista and running quite directly to filtration works near Antioch, thence to Walnut Creek, East Oakland, and Alameda and across the bay to Potrero Point, San Francisco.

For estimate cost of a filtered supply from Sacramento River see pages 135–137.

6. Feather River.—The lowest point on the Feather River at which water could be diverted and delivered by gravity to a pumping station at the base of the Coast Range Mountains in Contra Costa County, which, in turn, would raise it to such an elevation that it could then flow by gravity to Crystal Springs Reservoir or to San Francisco via Oakland, is in the vicinity of Big Bend on the North Fork or on the Middle Fork at about an equal distance (16 miles) above Oroville.

The drainage area of the North Fork of Feather River above Big Bend is 1,940 square miles. It contains a number of towns, including Quincy, Taylorsville, Crescent Mills, Greenville, and Prattville. The Western Pacific Railway parallels the river and its tributaries, Spanish and Indian Creeks, all the way from Oroville to Quincy, over 75 miles.

The Middle Fork drains the Sierra and Mohawk Valleys, agricultural lands, with several growing towns, and is paralleled by the Western Pacific Railway for 40 miles.

Although there are these several towns on the watershed and considerable stock raising, dairying and mining operations, the population per square mile of drainage area is very small, but with the facilities for transportation now provided by the Western Pacific Railway it will increase.

With the large run-off from the Feather River catchment area and with the great reservoir possibilities there is no doubt as to the possibility of its furnishing a sufficient quantity of water for San Francisco (400 M. C. D.) and supplying the irrigation requirements. (See statement as to low-water discharge and reservoir capacities on p. 86.)

The extent to which the great storage possibilities on North Fork of Feather River (mentioned in connection with discussion on Sacramento River) are likely to be developed is dependent on the demands for power and for irrigation. There has already been a considerable development of each. The Big Meadows reservoir is now under construction. The natural sterilization of water by storage in these distant reservoirs would be offset by mixing with the low-water flow of the river before the power plant is reached through which a city supply would pass. For a supply to be filtered the lower Sacramento, except in point of hardness, is much more advantageous than the Feather.

Mr. Grunsky's report on the Feather River, submitted to the board on August 1, recognizes that either the water must be filtered or stored below the point of intake in reservoirs for a sufficiently long period (30 days or more) to destroy pathogenic germs and suggests the possibility of such storage in the hills back of Martinez.

He makes estimates of cost of two alternative schemes—one for delivering filtered water by gravity at an elevation of 20 feet in San Francisco; the other delivering raw water at an elevation of 50 feet at Martinez, then pumping it to a storage reservoir above Martinez, from which it would be delivered by gravity to San Francisco at an elevation of 215 feet.

After adding to the cost of the gravity scheme, the value of the 195 feet difference of head in delivery to San Francisco, Mr. Grunsky finds that for a 200 M. G. D. supply the pumping proposition is slightly more economical; but he states that for a greater supply than this a filtration plant will be necessary to take care of the additional demand.

The estimated cost of plant and capitalized cost of operation for a Feather River supply of 60 M. G. D. is about 40 per cent greater than the estimated cost for supplying an equal quantity of filtered water from the Sacramento. For a 200 M. G. D. supply there is a slight advantage only for the Sacramento River.

7. *Yuba River.*—The entire region drained by the Yuba River has a heavy precipitation. It is also one of very rapid run-off, there being little natural storage in lakes or valleys except at the headwaters of the South Yuba.

Quite extensive reservoir systems have been developed here, and are capable of considerable extension. The South Yuba Water Co. furnishes water for mining purposes and for irrigation. The Excelsior Mining & Water Co. is the owner of quite extensive water rights. The Pacific Gas & Electric Co. uses water from both the South and North Forks for power development.

A group of lakes and reservoir sites which are drained by Canyon Creek, a tributary of South Yuba, and with which may be connected, by canal and tunnel, others on the upper Middle Fork, are controlled by W. B. Bourn, president of the Spring Valley Water Co. These constitute what is known as the Bowman Lake system. Reports made to Mr. Bourn on supplying water to San Francisco from the Yuba River with the Bowman Lake System as a necleus, by two engineers, Samuel Storrow and W. W. Waggoner, have been made accessible to the board.

These reports contain much valuable, though fragmentary, data as to the yield of the catchment areas of the Bowman Lake system, extending back to the year 1872. Substantially the same plan for developing the supply is followed in each case. The quantities of water estimated upon as dependable are doubtless sufficiently so to justify the necessary expenditure for power development, but are much greater than can be regarded as safe for a city water supply through critical periods.

Mr. Storrow goes rather more into detail as to possible yield, and his estimates of a dependable supply are more conservative than those of Mr. Waggoner, and in some instances even more than the results of this investigation show, though the résumé of his report would of itself convey a different impression.

The drainage area of the Bowman Lake system is made up of the following parts:

	Square miles.
Bowman Lake drainage area	29.08
Texas Creek drainage area	3.99
English Reservoir drainage area	11.80
Pass Creek drainage area	17.50
Total	62.37

Mr. Storrow estimates the average run-off from this area at 150.5 M. G. D., or 2.42 M. G. D. per square mile.

He estimates a conservation, by means of seven reservoirs (see p. 137), with an aggregate capacity of 30,867 M. G., of 51.4 M. G. daily. This latter is, however, based on the storage of 600 days' supply, which, although proper for the Tuolumne and Stanislaus watersheds, seems more than necessary for this portion of the Yuba, where, it is understood, there are no adverse water rights to reduce the available run-off.

The mass diagram (fig. 15) of flow per square mile from high Yuba River areas gives a mean run-off for six years (1903–1909) of 2.50 M. G. D. per square mile. The most critical season of this period was in 1907–8. A comparison of the mass diagrams of those streams for which there are run-off records both for 1897–98 and for 1907–8 shows that to maintain a given draft, storage for the former period would need be 50 per cent greater than for the latter.

Comparison of rainfall records and deductions therefrom as to run-off indicate that the storage required for the most critical periods that have occurred since 1849 may be 50 per cent greater than for 1897–98. (See discussion on rainfall and run-off, p. 72 et seq.) Therefore, with a total storage capacity of 30,867 M. G., the storage that could safely be applied to regulating the draft in 1907–8

(leaving proper reserve for worse periods) is $30,867 \div 1.50 \div 1.50 = 13,700$ M. G., or for the 62.37 square miles 220 M. G. (675 acre-feet per square mile). Referring again to the Yuba River diagram, 675 acre-feet storage per square mile will equalize a draft of 1.50 M. G. D. per square mile (+10 per cent for evaporation), or a total draft from

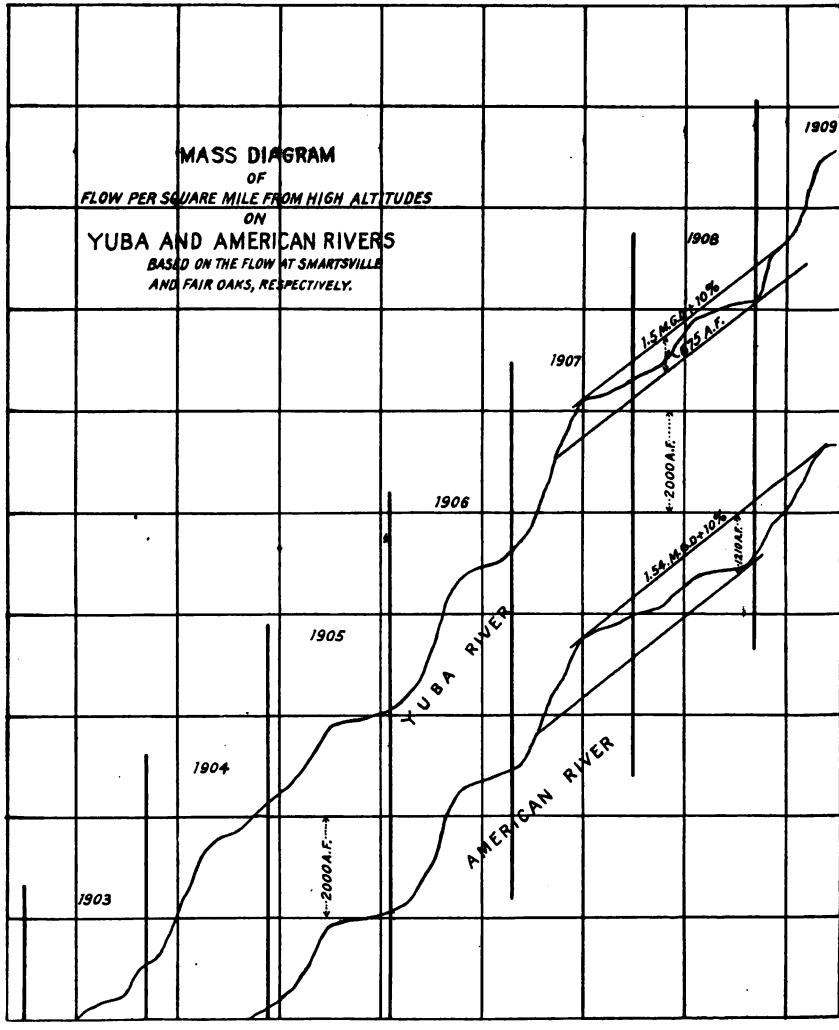

FIG. 15.—Mass diagram of flow per square mile from high altitudes on Yuba and American Rivers, based on flow at Smartsville and Fair Oaks, respectively.

the system of $1.50 \times 62.37 = 95$ M. G. D. The total storage capacity, 30,867 M. G., is a 325 days' supply at this rate.

To augment the supply from Bowman Lake system, Mr. Storrow proposes to conserve from 180 square miles on the South Yuba, of which 138 square miles are tributary to South Yuba Water Co.'s system, 18.33 M. G. D., by means of 10,996 M. G. storage, in reservoirs at Malakoff and Columbia Hill. A storage capacity of 600

days' flow is in this case probably necessary, as prior water rights are very extensive and may take the total run-off through much longer periods annually.

From 169.5 square miles of drainage area on Middle Yuba, exclusive of 11.8 square miles diverted to the Bowman Lake system through the English Reservoir, with an estimated annual run-off of 1.71 M. G. D. per square mile, Mr. Storrow, by means of a diverting canal of 750 second-feet capacity and two reservoirs, Sweetland and Shady Creek, at elevation about 2,000 feet, having a combined storage capacity of 30,408 M. G., estimates a conservation of 50.68 M. G. D.

The total supply from the Yuba which might thus be available for San Francisco is—

95	M. G. D. from Bowman Lake System	with 30,867 M. G. storage.
18.32	M. G. D. from South Yuba	with 10,996 M. G. storage.
50.68	M. G. D. from Middle Yuba	with 30,408 M. G. storage.
164	M. G. D. total.....	with 72,271 M. G. storage.

There are features of the proposed reservoirs at Malakoff, Columbia Hill, Sweetland, and Shady Creek that cause considerable uncertainty as to probable cost of construction and maintenance and as to the quality of the water. At Sweetland a large portion of the reservoir capacity is furnished by old hydraulic mining pits, the high gravel banks of which have stood vertically, or nearly so, for many years. When converted into a reservoir the action of water, especially wave action, would probably cause extensive caving of banks for a long time. The proposed height of this dam is 230 feet.

At Shady Creek the proposed dam is about 3,000 feet long and 180 feet high.

The Columbia Hill dam would be 2,000 feet long and about 200 feet high.

There are numerous mining camps on the Yuba River watershed, but these are situated mostly below the proposed points of diversion, and the drainage from them may be readily excluded from the ditches or conduits.

Three power plants are proposed: The first, called the Starr power plant, uses the water from Bowman Lake system under a head of about 2,000 feet; the second, called Waggoner, located on the South Yuba, about 22 miles below the Starr plant, will have a head of about 700 feet; the third, called the Bourn plant, uses, under a head of about 1,200 feet, the water that passes through the Starr and Waggoner plants and, in addition, that which is obtained from the Middle Yuba. The power so developed is more than sufficient to do the necessary pumping for delivering the water into Crystal Springs Reservoir.

The route proposed by Mr. Storrow, which is also an alternate route proposed by Mr. Waggoner, would deliver the Yuba water to a connection with the Spring Valley's pipes in the Livermore Valley.

But for a supply coming from the north, designed to serve the metropolitan district about San Francisco Bay, it would not be economical to carry it all around the cities of Oakland, Berkeley, and Alameda to the San Francisco peninsula.

The safe dependable supply, not requiring filtration, which it has been estimated above could be obtained from the Yuba River, is

164 M. G. D. For a larger supply, such as 400 M. G. D., estimated necessary for the metropolitan district of San Francisco by the close of the present century, the run-off from a much larger portion of the Yuba River watershed would have to be used. There is a catchment area of 1,220 square miles above the proposed point of diversion at junction of the North and South Forks.

The supply, which can be controlled by the reservoir system described above, together with the natural discharge from the remainder of the watershed, regulated to a considerable extent now, and to a greater extent in the future by reservoirs of power companies which use the water above the point of diversion, can doubtless be brought up to 400 M. G. D. Such a supply would need purification.

For a filtered supply or one requiring long time storage along the line of conduit, the Yuba River has no advantage over the Feather, except possibly a little more favorable crossing of the Sacramento Valley between Rocklin and Woodland, or the route proposed by Mr. Storrow, instead of crossing the Sutter Basin to Marysville Buttes, thence across the Sacramento River and Colusa Basin to the vicinity of Arbuckle, which Mr. Grunsky proposes for both the Yuba and Feather River conduits.

The cost estimate for an unfiltered supply of 164 M. G. D. given on page 137 is for delivery by gravity to San Francisco, no part of it being allowed for the cities on the east side of the bay.

The aqueduct line follows generally the route suggested by Mr. Grunsky to the west side of Sacramento Valley; thence along the line proposed for the Mount Shasta Aqueduct from about Cache Creek to San Francisco. A profile of the Mount Shasta Aqueduct line is shown on Pl. III.

This gravity conduit, with intake about 150 feet higher than proposed by Mr. Grunsky, of course requires larger and heavier pipe across Sacramento Valley than would one delivering water at about sea level in the vicinity of Carquinez Straits, where it would have to be pumped to a sufficient elevation for delivery to San Francisco

8. American River.—The American River, above the gauging station at Fair Oaks, drains an area of 1,910 square miles. The average run-off per square mile from the higher portion of this area is about 10 per cent less than that from the Yuba River, but it is considerably greater than that from the mountain areas to the south. As on all the other Sierra streams the claimed appropriations of water greatly exceed the total low-water flow. The question of the validity of many of these claims can be determined only by the courts. The power plant of the Pacific Gas & Electric Co., at Folsom, has a capacity of 1,750 second-feet, which alone exceeds the natural flow of the river for from three to six months each year. On account of its low elevation, and of probable contamination, water passing through this power plant can not be considered as a practicable supply for San Francisco.

There are several actual diversions from the river for irrigation and mining purposes and rights of others claimed. On some of the latter the necessary legal requirements as to prosecution of development work are being complied with, so that in time they too will become vested rights.

There are also other water-power plants and water-power projects in embryo, which depend mostly on stored water. These do, or will, return the water to the river above the points where diversion would need be made to a conduit for delivering water to San Francisco.

With the exception of a few reservoir sites on the Rubicon River, which form part of a power project now being developed, and one on Silver Creek which, on account of apparent desirability as shown on topographic sheet of United States Geological Survey, was examined by me in September 1911, and found to have just been surveyed by the Western States Power Co. for a reenforcement of its power plant, practically all of the reservoirs or suggested sites on the American River watershed are located at high altitudes and have very limited drainage areas.

Several different combinations of portions of the American River watershed or combinations with drainage areas of adjacent watersheds, affording greater or better storage, are possible.

Two propositions, neither of them recent, have been made to the city for furnishing water from the American and adjacent watersheds. They will be discussed separately under headings 8a and 8b.

8a. Giant Gap water supply.—This proposition, made in 1901, was for a daily supply of 45 M. G. from 212 square miles drainage area and with 39,000 M. G. storage capacity. One of the proponents has informed me that on account of inaccuracies in estimates of reservoirs (some being too large and some too small) the total capacity of the nine reservoirs would be about 25,000 or 30,000 M. G. This would be ample for the daily supply named.

This scheme has since been enlarged, though neither has a new proposition been made to San Francisco nor are the necessary properties in the control of the proponents to embrace diversion from the Yuba (South Yuba and Bowman Lake) and larger portions of the American watershed, making a total drainage area of over 800 square miles.

Some of the developments proposed are being made or are under consideration by other parties, but the combinations proposed may be possible. The Giant Gap project contemplates producing a continuous flow of 835 cubic feet per second (540 M. G. daily), of which 441 second-feet (285 M. G. D.) are for city supplies, the rest for irrigation and power only.

The report on this project by Russel L. Dunn, consulting engineer, gives no estimates of reservoir capacities, but, combining those of the smaller and earlier Giant Gap proposition with those of two other schemes, which this one proposes to absorb and on which estimates of reservoir capacities have been obtained, gives a total of about 105,000 M. G. The 800 square miles of drainage area with this storage capacity would yield a continuous flow greater than claimed through the dryest period if there were no prior rights to allow for.

As has been stated, the latter are quite extensive. Assuming that they are so great that storage for 400 days' supply may be necessary for driest period, the storage named would furnish 262 M. G. D., leaving none of the storage available for power or irrigation.

No comparative estimate of cost has been made for a water supply under this scheme on account of lack of data. The pipe line under

pressure would start from about the same point as in the Yuba River scheme (Rocklin-Woodland Route) and consequently the cost from that point for an equivalent supply would be about the same. If the other interests already mentioned could be harmonized, the indications are that the total cost of a Giant Gap supply would not exceed one of equal volume from the Yuba, and it might be considerably less.

8b. American-Cosumnes, or Bay Cities project.—Of the several propositions that have been made to the city for furnishing a source of supply, this one has been most prominently (excepting only the Tuolumne) before the public. In 1906 a proposition was made to the city for the sale of the properties and rights of the Bay Cities Water Co. on the American and Cosumnes Rivers. The merits of this source of supply were clouded by the political situation at that time and allegations of graft in connection with the proposition were made.

Notwithstanding the unfortunate circumstances attending its exploitation, the possible development of the American-Cosumnes water supply has been more thoroughly studied, or, at any rate, the results of studies which have been made available to this board are much more comprehensive than in the case of other sources under consideration.

The drainage area from which the Bay Cities Water Co. proposed to obtain its supply consists of 238 square miles on the South Fork of American River running up to the summits of the Sierras, and 158 square miles on the Cosumnes River, making a total of 396 square miles. Within this area 18 reservoirs, with aggregate capacity of 104,900 M. G., have been surveyed.

Edwin Duryea, jr., chief engineer, Bay Cities Water Co., estimates the continuous and dependable water supply at 317 million gallons per day. He also estimates that the fully developed American River area, with the Sly Park Creek area of the Cosumnes added, would supply 215 M. G. D.

The Bay Cities Water Co. has not at present a proposition before the city of San Francisco for supplying water from the Sierras. The rights which it acquired on the Cosumnes are no longer held by it.

On account of the insufficiency of reservoir capacity on the American at locations other than in close proximity to the crest of the mountains, the inclusion of Sly Park Creek, with 18 square miles of drainage area and the reservoir site, of large capacity, at Sly Park, is necessary for the economical conservation of American River water. Sly Park is at an elevation of about 3,500 feet. It is at about the uppermost point, on its watershed, permanently occupied. The reservoir site is now used for meadow and agricultural purposes.

For its larger supply the Bay Cities Co. proposed to use all of the Cosumnes River watershed above Bucks Bar, at which point was to be another large reservoir. Bucks Bar is at elevation 1,600 feet. The permanent population on the tributary drainage area is very small, but there is enough to require some supervision over it. This is not considered so desirable a catchment area for an unfiltered supply as others with which comparisons are made, and its possibilities are not further considered.

On the drainage area of South Fork of American, above its point of diversion at Slippery Ford and the tunnel through the ridge separating it from the Cosumnes watershed and on the Sly Park portion of

the latter, are the following-named reservoir sites with capacities and tributary drainage areas as given:

Reservoir.	Catchment area.	Capacity (acre-feet).		
		M. G.	Total.	Per square mile.
	Square miles.			
Silver Lake	15.3	16,570	50,800	3,320
Twin Lakes	13.0	7,640	23,400	1,800
Upper Caples Fork	20.2	1,650	5,060	707
Lower Caples Fork		2,200	6,750	
Kirkwood Meadows		800	2,450	
Audrain Lake	5.9	1,900	5,830	5,040
Echo Lake		7,760	23,800	
Medley Lakes	1.8	9,390	28,800	16,000
Alder Creek	17.6	6,700	20,550	1,165
Slippery Ford	.....	9,000	27,600	.....
Sly Park	18.4	11,000	33,750	1,830
Total	.....	74,610	228,790	.....

A study of these figures, together with the mass diagram of flow per square mile from high areas of American River (fig. 15), shows that each of the reservoirs excepting those on Caples Fork and Alder Creek and the one at Slippery Ford have greater capacity than needed to equalize the run-off from its drainage area through the period 1907–1909. In the case of the Medley Lakes the excess capacity is so great that it would require the accumulated run-off of several years to fill it, and when filled the loss by evaporation would be greater than the mean run-off for the two seasons 1907–1909.

The excess capacity of Sly Park is needed to aid in conservation of the flow of the South Fork of American.

The three reservoirs on Caples Fork are very uneconomical in regard to amount of material required for dams in proportion to volume of water stored. Eliminating these and reducing the Medley Lakes capacity to 9,000 acre-feet makes the total available storage 194,700 acre-feet.

A period which has been assumed to require the greatest storage capacity is one requiring two and a quarter times (1.50×1.50) that for an equal draft for the period 1907–1909. (See discussion on Yuba River.) Therefore, the portion of the total capacity that could be properly applied to the regulation of the discharge of the latter season is the total capacity divided by 2.25.

A storage capacity of 194,700 A. F. $\div 2.25 = 86{,}500$ acre-feet in connection with the run-off from 256 square miles (238 on American and 18 on Sly Park Creek) would yield, according to the mass diagram (fig. 15) 215 M. G. D.

Through the assumed worst possible season the total storage capacity (194,700 A. F.) would permit the same daily draft.

The above figures make no allowance for adverse prior rights, it being understood that the Bay Cities Co. owns all of those on the South Fork of the American; and that those on Sly Park Creek may be reasonably acquired.

The plans of Bay Cities Water Co. so far as outlined in their offer to the city contemplated a power plant at Cat Point, using water from

a high and from a low level canal. The latter would be eliminated with the Bucks Bar Reservoir and drainage area.

A considerable portion of the report on the American-Cosumnes project by J. H. Dockweiler, submitted August 1, 1912, is devoted to the water requirements of adjacent areas in the Sacramento Valley and foothills.

The conclusion of an investigation "based on the broad theory of water conservation" is "that all water rights, commercial industries, and irrigable lands having claim upon the waters of the drainage areas of the American-Cosumnes project can be fully and justly met and still leave available for San Francisco and the Bay cities 223.6 M. G. daily."

For a yield of this quantity Mr. Dockweiler includes the drainage area tributary to Bucks Bar below Sly Park.

The dependable yield of 215 M. G. D. estimated by me was for a catchment area including only 18 square miles on the Cosumnes River instead of 158. This yield agrees with Mr. Duryea's for the same catchment area. An estimate of cost of a 215 M. G. D. supply from the American-Cosumnes, combined with one of 128 M. G. D. from the Mokelumne and of 57 M. G. D. from the Stanislaus, making a total of 400 M. G. D., will be found on pages 133–134.

9. Lake Tahoe.—Several schemes have been proposed for extensive utilization of the waters of Lake Tahoe by diverting them by means of tunnels to the west slope of the Sierras and to the east slope of the divide separating the lake from the Carson River in Nevada.

For power production, diversion to the west offers great attraction on account of the much greater possible head under which the water may be used than is possible along the Truckee River or by diversion to Carson Valley.

But there are now several power plants on the Truckee, and the Truckee-Carson irrigation project uses a large volume of water and contemplates greater use, this latter being dependent on large storage capacity.

An engineer's report, dated October, 1908, on the utilization of Lake Tahoe water for a municipal supply was submitted to the board in July, 1911. Two of the features of this report were claims to the flow from Lake Tahoe up to 1,200 second-feet, and estimate of a continuous dependable supply of 561 second-feet.

The United States Geological Survey records of the discharge from Lake Tahoe for the nine seasons, 1900–1901 to 1908–9, show a mean daily discharge ranging from 123 second-feet to 870 second-feet, the average for the nine seasons being 426 second-feet (275 M. G. D.). During the years 1908–9 the flow at no time exceeded 900 second-feet.

On account of the extensive use of this water, present and prospective, in the region through which it has its natural outlet, it has not seemed necessary to inquire into the practicability of sufficient storage to regulate the flow to the mean of the nine-year period. Since the extreme variation in seasonal discharge from the lake during the nine years corresponds to a depth of water over its surface of but little more than 4 feet there should be no difficulty in this, and probably not to equalize the discharge at the same rate through much drier periods than those for which there are records.

The reason for the comparatively small run-off for so large a drainage area is not due so much to the fact that it lies on the east side of the Sierra divide as to the large proportion of the drainage area

occupied by the lake itself, with consequent large evaporation loss. The area of the lake is about 193 square miles, and of the drainage area (including the lake) 519 square miles.

10. Mokelumne River.—Water supply investigations made for the city of San Francisco, 1874–1877, resulted in the recommendation, by Col. G. H. Mendell to the board of water commissioners, of the Mokelumne River for a source of supply.

In Col. Mendell's report occurs the statement that for a conduit of 25 M. G. D. supply there should be 2,000 M. G. storage (an 80 days' supply). For so small a supply from a stream on which the use of water had not been greatly developed, although rights to large volumes of the flow of the stream were claimed, the necessity for very great storage capacity was not so apparent as at present. For the much larger daily yield now sought from drainage areas in the Sierras, storage capacity of from 300 to 900 days' supply is needed, depending on the area of the watershed, its run-off depth, and the extent to which other uses of the flow of the stream must be allowed for.

Russel L. Dunn, consulting engineer, in report dated July 30, 1908, to the Sierra Nevada Water & Power Co., estimates that with the storage capacity (20,000 M. G.) afforded at Rail Road Flat Reservoir site, at junction of South and Licking Forks of Mokelumne River, with a dam 290 feet high, and with 536 square miles of drainage area, most of which is not naturally tributary to this reservoir, but is to be made so by diverting canals, 125 M. G. D. is the limiting quantity of water that could be supplied to San Francisco through a year like 1898.

The rights of the Sierra Nevada Water & Power Co. were based primarily on filings made by W. V. Clark, sr., in 1856 and subsequently. The actual use at present made by the successors of Clark is very little.

The Sierra Blue Lakes Water & Power Co. has succeeded to the rights of the Sierra Nevada Water & Power Co., and has filed on others. It has made offers for the acquirement of its rights and properties by San Francisco and claims they will yield 200 million gallons daily. Some of its later publications claim a daily capacity of 500 million gallons. The rights to water now used, which must be allowed for in estimating the yield from the upper Mokelumne River drainage area, are:

Pacific Gas & Electric Co., 175 second-feet, of which 77 second-feet may be diverted from the drainage area (old Amador Canal).

Mokelumne River Power & Water Co. (Prindle ditch), 75 second-feet.

Woodbridge Canal, 62.5 second-feet, from April to September. (As the point of diversion for this canal is below the power plant of the Pacific Gas & Electric Co., the water from the latter may again be used).

Other claims which must be considered are those of the Mokelumne Power & Water Co. to 250 second-feet of flood-water flow of Middle Fork, for the diversion of which to Calaveras Valley a ditch is now under construction, and the Mokelumne River Power Co. to 175 second-feet of flood water of the North Fork, which it proposes to store in a reservoir located on this fork above the mouth of Moore Creek.

The records of the United States Forestry Service show that filings for this reservoir site antedate those of Sierra Blue Lakes Water & Power Co. for the site at mouth of Blue Creek.

No extensive use of Mokelumne River water for irrigation is made at present, but a study of the location of lands in the Sacramento and San Joaquin Valleys, which are irrigated, and their relation to the drainage areas from which the water comes for their irrigation, does not confirm the statements of advocates of the Sierra Blue Lakes scheme that the waters of the Mokelumne are not needed for irrigation.

In fact it appears that the ratio of catchment area to the dependent irrigable area is less in the case of the Mokelumne than in the case of either the Stanislaus or the Tuolumne. The difference is partly compensated for by somewhat greater precipitation on the Mokelumne areas.

Mr. Grunsky's report, submitted August 1, 1912, takes up the subject of irrigation needs of the district that would properly be served by the Mokelumne. He estimates that there are 200,000 acres, requiring 600,000 acre-feet of water annually. (See additional discussion of irrigation needs on page 101.)

The reservoirs now proposed by the Sierra Blue Lakes Water & Power Co. for the conservation of its Mokelumne River supply, with their capacities, depths of water, and approximate heights of dam, are as follows:

Location.	Depth of water.	Approximate total height of dam.	Capacity.	
			Acre-feet.	M. G.
Junction of South and Licking Forks, Mokelumne River (Rail Road Flat)	*Feet.* 300	*Feet.* 325	66,000	21,500
North Fork of Mokelumne River at mouth of Blue Creek	300	325	86,000	28,000
Forest Creek or North Branch of Middle Fork of Mokelumne River	110	125	2,800	915
Blue Lakes	.....	36	[1]	[1]

[1] See below.

The capacities given for the Rail Road Flat and North Fork Reservoirs were determined from surveys made by the city of San Francisco after reconnoissance had been made by me. The dams required are very large in proportion to storage capacity. The capacities of Forest Creek Reservoir were determined from my reconnoissance survey. The capacities claimed by the proponents of the "Blue Lakes" scheme are much in excess of these.

Storage at the Blue Lakes is now used by the Pacific Gas & Electric Co. in connection with its power plant at Electra. The right to raise the Blue Lakes Dams and to use the additional storage, claimed by the Blue Lakes Co. (and backed by legal opinion) is of very little value, as the present capacity conserves practically all of the run-off from the catchment area, 4½ square miles.

The Mokelumne River mass diagrams (fig. 16) show the estimated run-off for several periods from the 642 square miles of drainage area above the gaging station, near Clements, and for portions of the watershed tributary to the reservoirs and diverting canals proposed by the Sierra Blue Lakes Water & Power Co. as follows:

Lines marked "*A*" show total discharge at station near Clements.

Lines marked "*B*" show total discharge at point of diversion, on North Fork, to Electra power station, for three periods—1886–1890, 1897–1899, and 1907–1909.

Lines marked "*C*" show water available to Sierra Blue Lakes Water & Power Co. at the site of its proposed North Fork Reservoir, after allowing 175 second-feet (or total flow when less than this) to Electra power plant and Amador Canal, as long as that flow can be maintained with the aid of 24,800 acre-feet storage. This is the combined storage capacity of three reservoirs of the Pacific Gas & Electric Co., Blue Lakes, Meadow Lake, and Bear River. The claims of the Mokelumne River Power Co. are ignored in this diagram.

Lines marked "*D*" show water available to Sierra Blue Lakes Water & Power Co. at same point as above, after allowing 350 second-feet (or total flow when less than this) to Electra power plant and Mokelumne River Power Co. as long as that flow can be maintained with the aid of 76,300 acre-feet storage. This is the combined storage capacity of Pacific Gas & Electric Co., as above, and of the proposed reservoir of the Mokelumne River Power Co. on the North Fork, above Moore Creek.

Lines marked "*E*" show water available to Sierra Blue Lakes Water & Power Co. from Middle, Licking, and South Forks after allowing 75 second-feet (and the entire flow when less) to Mokelumne River Power & Water Co. (Prindle Ditch).

Lines marked "*F*" show water available to Sierra Blue Lakes Water & Power Co. from Middle, Licking, and South Forks after deducting the flow from 25.2 square miles of Middle Fork (above Prindle's proposed diversion to Calaveras reservoir) up to 250 second-feet (capacity of Prindle's proposed diverting ditch) at times when flow at Rail Road Flat Reservoir is in excess of 150 second-feet (the approximate combined capacity of the old Prindle and Clark Ditches).

With the reservoir capacities shown on page 98 the possible draft during critical periods as shown by the lines *D* and *F* are:

	M. G. D.
For period 1887–1889:	
From North Fork	114
From South, Middle, and Licking Forks	70
Total	184
For period 1897–1899:	
From North Fork	120
From South, Middle, and Licking Forks	65
Total	185
For period 1907–1909:	
From North Fork	111
From South, Middle, and Licking Forks	81
Total	192

In accordance with the deductions from rainfall data as to the possible conservation during the most critical periods that have occurred since 1849 (see p. 78), which have been applied to other catchment areas, the safe dependable continuous yield from these areas with the given reservoir capacity, holding one-third of this capacity in reserve for periods drier than any of those shown by diagram, is 128 M. G. D.

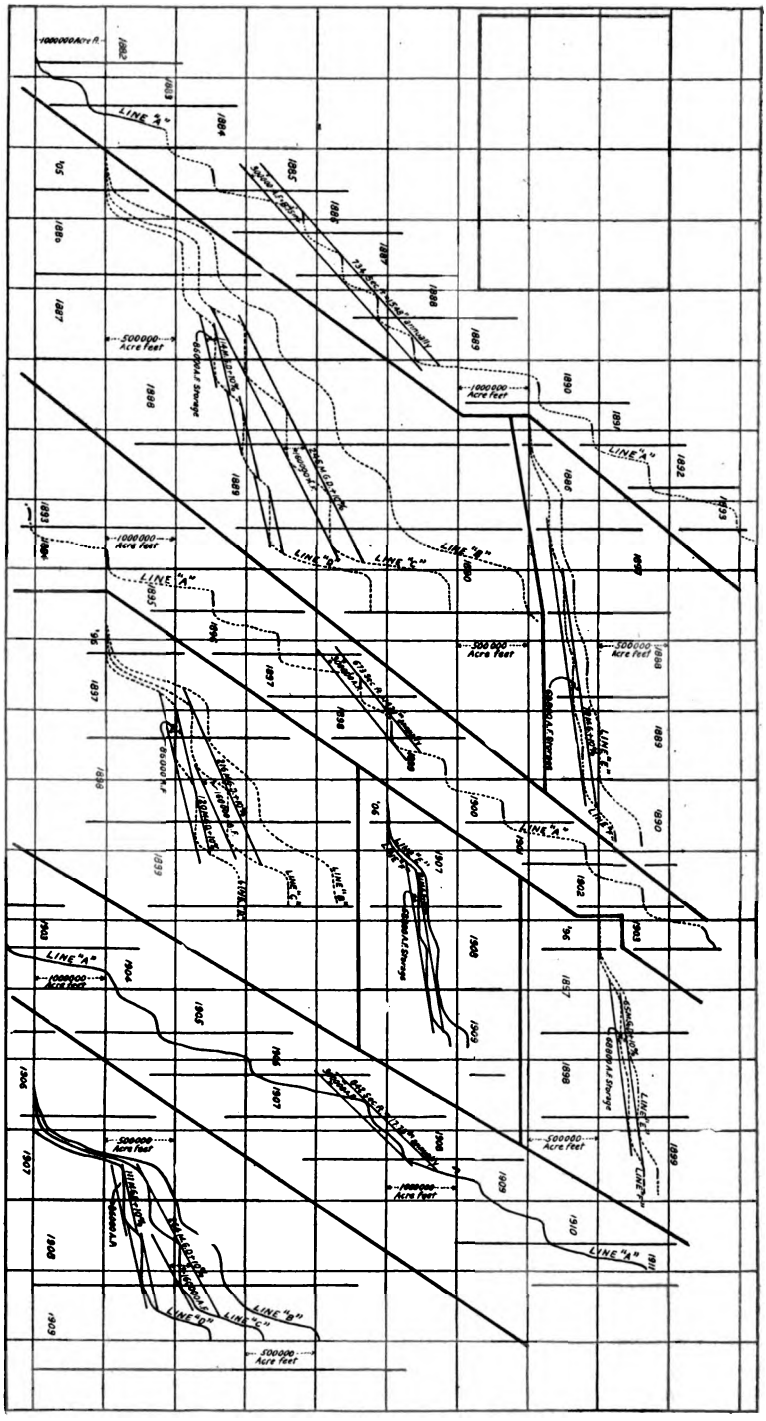

FIG. 16.—Mass diagram of flow in Mokelumne River. Line *A* shows total discharge at Clements. Line *B* shows total discharge at point of diversion to Electra Power Plant. Lines *C*, *D*, *E*, and *F* show water available to Sierra Blue Lakes Water & Power Co., at different points and with different allowances for adverse rights. (See text, p. 100.)

To increase the dependable yield through the driest periods to that shown possible through several dry periods, viz, 185 M. G. D., and to allow for the same prior rights, an increase of 50 per cent, or 77,000 acre-feet, in storage capacity is necessary. This additional capacity for use during extremely dry seasons only might be so located as to be filled during extremely wet seasons only. Surveys made by the United States Geological Survey on the Mokelumne River catchment area, have covered three sites, all above elevation 7,000 feet, aggregating 2,530 acre-feet capacity, only about 3 per cent of required increase.

The draft possibilities from this system could be increased considerably by including in the catchment area contributory to the supply the territory between the reservoirs on the North Fork and at Rail Road Flat and the point of final diversion to conduit below Rich Gulch. But within this territory are several small settlements and a number of ranches. Its exclusion conforms to the manner of treating the other sources of supply. The catchment area from which the proposed supply would be taken has very few permanent inhabitants. For a few months each year it is used for cattle grazing.

By combination of the Sierra Blue Lakes Water & Power Co.'s appropriations of water and reservoir sites with the rights of other appropriators, as, e. g., the Mokelumne River Power Co., or of this company and the Pacific Gas & Electric Co. on the North Fork, and diverting the water below the Electra power plant, or with the Mokelumne River Power & Water Co. (Prindle Ditch) on the South and Middle Forks, the yield may be greatly increased.

The lines *B*, *C*, and *E* of the mass diagram afford the means of determining the possibilities of such combinations.

Claims made by this company to a reservoir site at Case Valley and to water rights on the Cosumnes River can not properly be considered in connection with the Mokelumne River, as such a combination is not feasible.

To determine the storage capacity necessary to meet an annual irrigation requirement of 500,000 A. F. (2.5 feet depth over 200,000 acres, instead of 3.0 feet depth assumed by Mr. Grunsky) together with that needed to insure for San Francisco a dependable supply through all seasons of 128 M. G. D., as determined above, an application to the mass diagram of discharge at Clements (lines *A* on fig. 16) of draft lines (not shown) for 128 M. G. D. plus 500,000 A. F. distributed uniformly through seven months (March to September, inclusive) shows that 250,000 A. F. storage would be sufficient for any period shown except 1898–99 when about 500,000 acre-feet would have been required.

Mr. Grunsky's deductions are not inconsistent with these. He shows that to have supplied 200 M. G. D. and to have met an annual irrigation requirement of 600,000 acre-feet a storage capacity of 1,000,000 A. F. would have been required for the period 1898–1900, but he states that "with storage in half this amount there would be a deficiency only in the rare case of such a critical period as that of 1897–1900."

The existing and proposed reservoirs of operating power companies, together with a number of small capacity reservoirs at sites that have been reported upon by various parties, would give the storage capacity in addition to that required for a 128 M. G. D.

supply required for full irrigation on the basis assumed by me above, except through extremely dry periods.

For estimate of cost of a Mokelumne supply in two different combinations to make a total of 400 M. G. D., see pages 131–133.

11. Stanislaus River.—The watershed of the Stanislaus River lies between those of the Mokelumne and Tuolumne.

The situation, so far as a possible city water supply is concerned, is controlled by the Sierra & San Francisco Power Co., which now furnishes power to the United Railroads of San Francisco. This company has a power plant at Stanislaus, at the junction of the North and Middle Forks of the Stanislaus River, which has a capacity of 400 cubic feet per second.

According to the statement of the manager of the company there is now, with one reservoir of 15,800 acre-feet storage capacity constructed, a dependable low-water flow through its canal to the power house from Sand Bar Flat, on the Middle Fork, of 132 cubic feet per second, or 85 M. G. D.

The mass diagrams (fig. 17) show this to be true for all seasons since records of the flow of the river have been kept by the company, or since 1905. Through a year like 1898 there would have been but little shortage. The entire dry-weather flow may be used for generating power, since the water is returned to the river above the points of use by prior appropriators; but for a supply for diversion outside of the watershed only water in excess of prior rights on the stream below can be used.

Two irrigation districts, the Oakdale and the South San Joaquin, claim the natural flow of the river up to 1,700 cubic feet per second. These districts are now constructing works to enable them to use the water to much better advantage than heretofore. Other small appropriations bring the total well up toward the 2,000 second-feet allowed in computing quantities for mass diagrams of water which might be made available for the use of San Francisco.

The necessary allowance for prior rights constitutes so large a portion of the total flow that, for a period like 1897–1899, draft would have to be entirely from storage for 21 months. During 1907–1909 there was a period of 17 months during which the natural flow that could have been diverted amounted to only about 10,000 M. G., or a 50 days' supply of 200 M. G. D. Greater storage in proportion to the daily yield is needed than for any of the other sources studied. Additional catchment area, without additional storage, will not increase the yield; compare mass diagram for the 615 square miles above the confluence of North and Middle Forks with that for the 320 square miles above Sand Bar Flat.

The Sierra & San Francisco Power Co. has guarded against other parties using the water stored by its reservoirs after it passes the Stanislaus power plant by itself acquiring a power plant near Knights Ferry, well down in the foothills, and using it again under a head of 14 feet. From surveys made for the Sierra & San Francisco Power Co. and from maps filed with applications for use of reservoir sites on public lands, there has been estimated a storage capacity of 170,000 acre-feet on the Middle Fork of the Stanislaus River. With this storage there could have been supplied through the dry period 1907–1909, 118 M. G. D.; through the longer dry period 1897–1899, 81 M. G. D.; and through the assumed longest possible

dry period, as in the case of other sources, 57 M. G. D. The estimated storage capacity is equivalent to 975 days' supply at this rate.

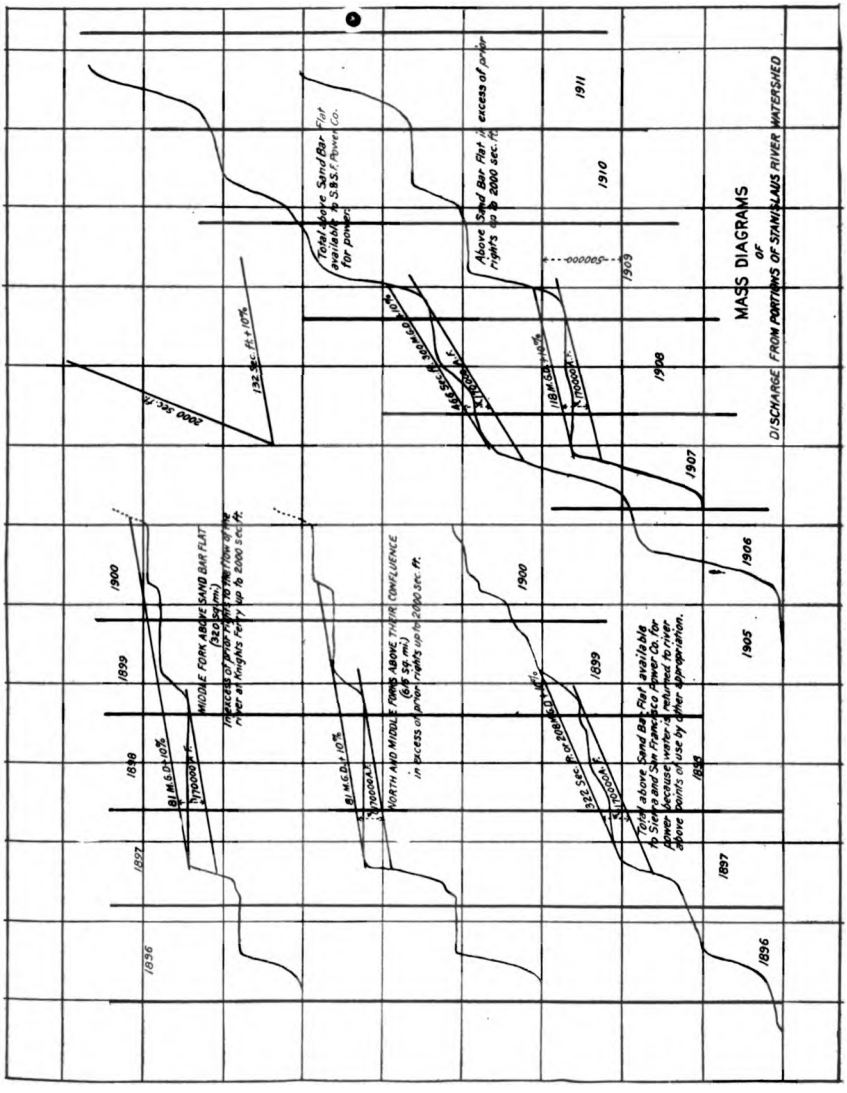

FIG. 17.—Mass diagram of discharge from portions of Stanislaus River watershed.

Mr. Grunsky, in his report of July 31, 1912, after discussing the developments made by the Sierra & San Francisco Power Co. and its predecessors; and the irrigation needs of the lands, rather than the

appropriations of the districts, dependent on the Stanislaus River, says:

> It does not seem reasonable to hope for an extension of such a project [supply from Stanislaus] to a greater capacity than 60,000,000 gallons per day, and even this amount it may be difficult, if not impossible, to secure continuously.

Compare with this statement, the 57 M. G. D. estimated capacity above.

The acquirement of the reservoirs and water rights of the Sierra & San Francisco Power Co. for a water supply would properly involve also the purchase of the power plants of that company, which have a capacity to use much more water than could be diverted to San Francisco.

A proposition made a few years ago by this company to San Francisco for furnishing water explicitly stated that it would grant no power rights. The power developed is now used by the United Railroads of San Francisco. Presumably there may be considerable extension of its use in this direction.

In the estimates of cost of a supply from the Stanislaus in combination with other supplies to make a total of 400 M. G. D., the possibility of utilization of power from this river is not taken into account.

12. Tuolumne River.—Above the United States Geological Survey station at La Grange the Tuolumne River has a drainage area of 1,500 square miles.

At La Grange Dam water is diverted to the canals of the Turlock and Modesto irrigation districts. Much has been said and written about guarding the water rights of these districts and supplying its further needs and those of adjacent lands which must look to the Tuolumne, if at all, for water.

Edwin Duryea, jr., chief engineer, Bay Cities Water Co., several years ago, prepared a voluminous discussion of the subject, tending to show that these land requirements and San Francisco's needs can not be supplied from the Tuolumne. This conclusion was based on the assumption that the capacities of reservoirs at Hetch Hetchy Valley and at Lake Eleanor, as given in the reports of C. E. Grunsky, former city engineer, were the limiting ones, and that those for several other reservoir sites, as published in reports of the United States Geological Survey, made up the total available storage capacity (270,000 acre-feet).

Even had this been the case there would have been no legal rights of the Turlock and Modesto districts interfered with so long as no water was stored by San Francisco except when the flow of the river at La Grange exceeded the amount of those districts' appropriations, viz: 2,350 cubic feet per second. But in the light of the fact that much greater storage is possible, a further investigation as to irrigation needs and their effects, if provided for, on a city water supply from the Tuolumne has been made.

It is now a well-recognized fact that the lands of many districts have been greatly overirrigated, and expensive subdrainage works have in some cases become necessary to restore them to fertility.

Mr. Burton Smith, superintendent of the Turlock irrigation district, says, December 31, 1910, that under present conditions, i. e., with no storage, the water supply is exhausted about the middle of July each year.

This creates a desire among the irrigators to give the land an overdose of water during the irrigation season.

This causes the water table to fluctuate rapidly and creates a condition very damaging to most crops. With a storage reservoir which the district now plans to construct, it is not expected that more water will be used, but that it will be more advantageously distributed. Mr. Smith says that at present about 3½ feet depth of water is used on the lands irrigated, and that he thinks 2½ feet will be ample.

In the report filed by the Turlock and Modesto districts on November 1, the need of a depth of 2.75 feet on the land annually is claimed. Among the showings made by them are results of experiments at the California State farm at Davis on growing alfalfa, which requires more water than most crops. These show that a depth of 2½ feet gives more economical results than either a greater or less quantity.

The combined area of the Turlock and Modesto districts is 402 square miles. It has been estimated, according to some of the earlier discussions, that an additional area, amounting to 60 per cent of the above, or a total of 643 square miles (411,520 acres), is dependent upon the Tuolumne for irrigation.

A map issued by the United States Department of Agriculture in cooperation with the conservation commission of California, an advance copy of which has been furnished the board, shows that the total area of irrigable lands east of the San Joaquin River and extending from the Stanislaus River on the north to the Merced River on the south, excepting so much of this area as is included in the Oakdale irrigation district, which takes its water from the Stanislaus, is approximately 690 square miles.

Six hundred and forty-three square miles is considered a generous estimate of the area dependent on the Tuolumne for water.

The report by J. H. Dockweiler, on the needs of Turlock and Modesto irrigation districts, submitted June 30, 1912, not only does not recognize any appreciable area outside the Turlock and Modesto districts dependent upon the Tuolumne for water, but, considering the water-logged condition of some of the lands within the district, estimates the maximum acreage requiring irrigation in any year at 206,000.

In view of the fact that the water-logged condition is only a temporary one, drainage being readily obtainable by ditching, and the further fact that applications for admission to the districts have been made by the owners of adjacent lands, there seems no necessity for so belittling the irrigation needs.

It may quite possibly be that the area outside of Turlock and Modesto districts, estimated above as dependent on the Tuolumne for water, is somewhat too large, but if so, there is a thirsty area on west side of San Joaquin to which excess water could be piped and where it could be advantageously used.

It is probable, however, that the present practice of irrigating such of the west side lands as can not be reached by gravity ditches, viz, by pumping from the San Joaquin River, is the more economical.

With increased use and better distribution of water on the east side, made possible by storage, the seepage back into the river will increase the supply available for such pumping.

For this investigation no change has been made in the area, as noted above, which might properly be irrigated from the Tuolumne.

Assuming that 85 per cent of the land will in time be irrigated, allowing for roads, buildings, corrals, etc., and that there may be a 15 per cent loss by seepage and evaporation in ditches, 2½ feet depth for the total acreage, measured at head gates, will suffice.

For the purpose of this investigation the use of irrigation water is assumed to be distributed through the season as follows:

	Feet.	Cumulative sums.		Feet.	Cumulative sums.
January	0.00	0.00	August	0.36	1.97
February	.00	.00	September	.36	2.33
March	.17	.17	October	.17	2.50
April	.36	.53	November	.00	2.50
May	.36	.89	December	.00	2.50
June	.36	1.25			
July	.36	1.61	Total	2.50	

Mr. Dockweiler estimates an annual requirement of 2.5 feet depth of water on the land, but he assumes a distribution of this water pro rata to the actual distribution of 1911, which obtained simply because no better distribution was possible without much greater storage capacity. Such a distribution, with the maximum rate of application of water to the land conforming in time to the maximum rate of discharge of the river, enables Mr. Dockweiler to show necessity for comparatively small reservoir capacity.

The following table shows the distribution of 2½ feet depth of water through the year, proposed by Mr. Grunsky in his reports on the Mokelumne and Stanislaus Rivers, and the same total quantity distributed according to the monthly percentages stated in the report of the Turlock and Modesto districts to be the probable average use:

	C. E. Grunsky.		Turlock and Modesto districts.	
	Monthly depths.	Cumulative sums.	Monthly depths.	Cumulative sums.
January	0.025	0.025	0.050	0.050
February	.050	.075	.075	.125
March	.100	.175	.100	.225
April	.200	.375	.200	.425
May	.375	.750	.375	.800
June	.500	1.250	.400	1.200
July	.450	1.700	.400	1.600
August	.375	2.075	.350	1.950
September	.250	2.325	.325	2.275
October	.125	2.450	.150	2.425
November	.025	2.475	.050	2.475
December	.025	2.500	.025	2.500

According to each of these proposed distributions the total to the end of June is practically the same as assumed by me above, and the variations (especially after June) are so slight as not to affect storage necessities.

Two and one-half feet depth over 643 square miles amounts to 1,028,800 acre-feet, or allowing 10 per cent for evaporation from reservoirs and other losses above head gates, or elsewhere, not covered by 15 per cent allowance previously made, the total annual need will be 1,132,000 acre-feet.

Compare with this estimated need (1,132,000 A. F.) of the greatest area that can be considered as dependent for irrigation on the Tuolumne River for water, the conclusions of the Turlock and Modesto districts (report of Nov. 1, 1912) that "the maximum quantity used from the river in any one year will not be less than 1,042,043 acre-feet."

The former quantity is based on 2.5 feet depth over 85 per cent of 643 square miles area, with total loss by evaporation and seepage of 23 per cent; while the latter quantity is based on 2.75 feet depth over 90 per cent of 402 square miles area, with evaporation and seepage losses of 39 per cent.

On the next page is a mass diagram of the total flow of the Tuolumne at La Grange from 1895 to 1912. There is also shown for the years 1896–1900, the yield of the Turlock and Modesto appropriations, i. e., 2,350 second-feet, when the flow was so much, or more, and the entire flow when it was less.

In the lower right-hand corner are shown four draft lines, one for 400,000,000 gallons daily, one for the irrigation requirements as above (1,132,000 A. F. annually), one for these two combined, and one for the irrigation needs of the 402 square miles constituting the Turlock and Modesto districts on the basis of 2.5 acre-feet per year, with 85 per cent of the land under irrigation.

The combined draft line, applied to the mass diagram, shows that the combined requirements of 400 M. G. D. for the city and 2½ acre-feet per acre per year for 643 square miles could be supplied by the river with annual drafts from storage of from 300,000 to 700,000 acre-feet, excepting only the years 1898, 1908, and 1912.

To have permitted full irrigation through 1898 and the two succeeding years a storage capacity of 1,400,000 acre-feet would have been required; for the year 1908, 890,000 acre-feet.

In 1912 the depletion of storage up to October 31, would have amounted to 900,000 acre-feet, or practically the same amount as on December 31, 1908.

With a total storage capacity of 750,000 A. F. or 50,000 more than the maximum required for full irrigation during other years than these, there would have been, after allowing the full draft of 400 M. G. D. for city supply, in 1898, a shortage of about 40 per cent in water for irrigation, i. e., a depth of 1.5 feet only could have been applied to the land that season instead of 2.5 feet. Likewise the shortage in 1908 would have been about 14 per cent, i. e., 2.15 feet could have been applied to the land.

Similarly a comparison of the needs of the 402 square miles comprising the Turlock and Modesto districts, with the yield of their water rights, shows that to supply from these rights alone 2.5 feet depth of water over the irrigable area a storage capacity of 270,000 A. F. would have been sufficient for any of the years except 1898, when an additional storage of 100,000 A. F. would have been required; or there would have been a shortage of about 16 per cent for that year.

As a result of statements made at the hearing before the Secretary of the Interior at Washington, November 25 to 30, 1912, the question arose as to whether the conservation of Tuolumne River water to the extent described above was not dependent on the use of water from the areas outside of the Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds to an extent impossible of attainment, on account

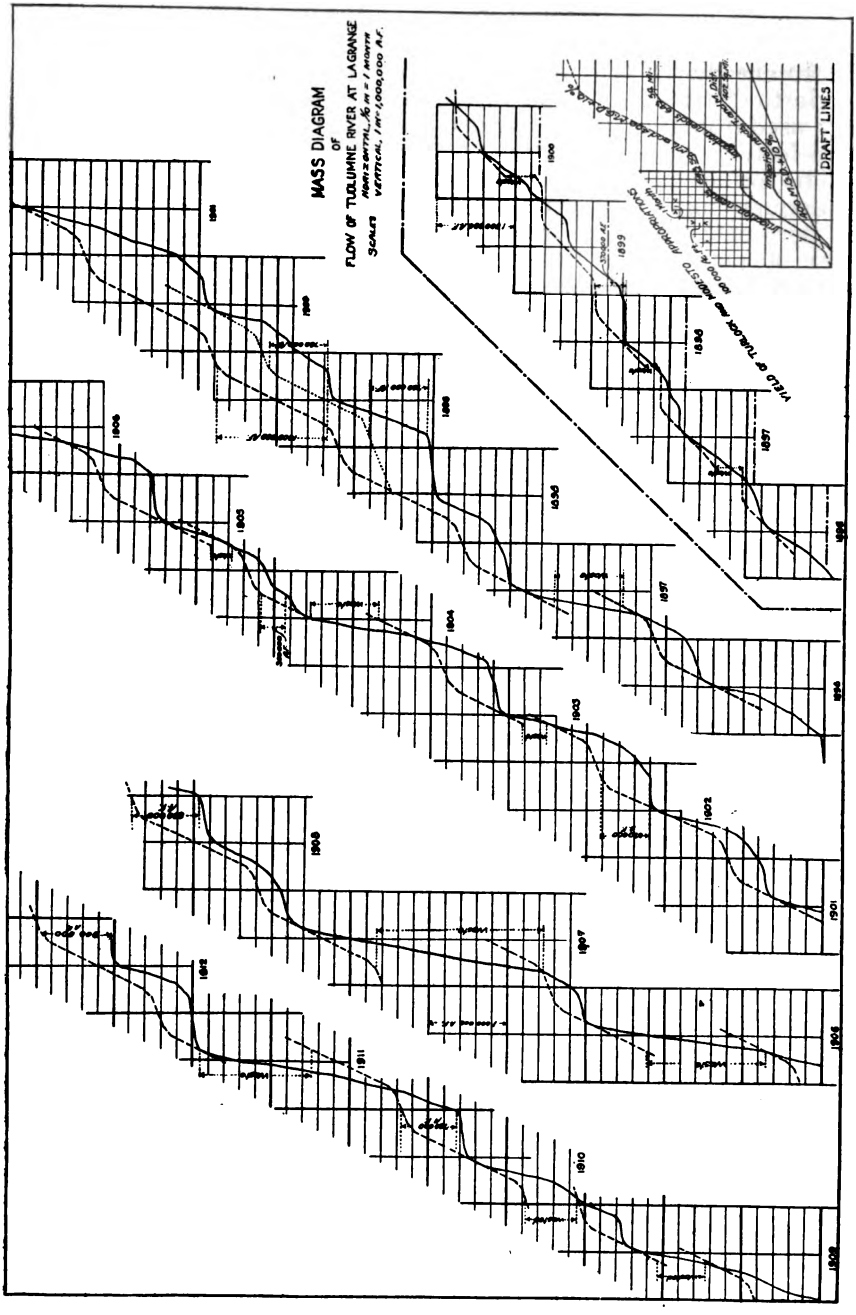

FIG. 18.—Mass diagram of flow of Tuolumne River at La Grange.

of lack of storage possibility on these outside areas or at locations to which the water could be diverted.

Further study has been given this question. A mass diagram of the run-off from the 848 square miles (1,500–652) in question, for the years from 1895 to 1901, has been platted, taking for each month the difference between the measured run-off at La Grange and the estimated run-off for the Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds as previously determined. Then assuming that 230,600 A. F. (see lower part of table, p. 111) is all the practicable storage on the watershed in question, and assuming the use of water for irrigation on the basis of 1,132,000 acre-feet per year with monthly distribution as stated by the engineers of the Turlock and Modesto irrigation districts to be desirable, it was found that, making such distribution of the water so far as could be effected with the stated storage, there would have been wasted in 1897 460,000 A. F., and in 1901 500,000 A. F.

From the total watershed of 1,500 square miles, and with the combined use of water for San Francisco (400 M. G. D.), and for the irrigation of 643 square miles of irrigable lands (see fig. 18), there would have been wasted in 1897, 880,000 A. F. In 1901, with total available storage, 750,000 A. F. the waste would have been 800,000 A. F.

Thus in 1897 the waste from the 848 square miles would have been 7½ per cent less than the proportionate part of the total waste from the whole 1,500 square miles. In 1901 the waste from 848 square miles would have been about 10 per cent more than the proportionate part of the waste from the whole 1,500 square miles.

With greater total available storage than 750,000 A. F. as e. g., 900,000 A. F., as was suggested as possible on page 111, there would have been wasted in 1901 about 500,000 A. F. of the total run-off from the 1,500 square miles, or the same quantity which it has just been shown would necessarily have been wasted from the 848 square miles with 230,000 A. F. available storage capacity. This simply means that all of the unavoidable waste from the total Tuolumne watershed would have been from the 848 square miles outside of the Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds.

The conclusion is that the possible conservation of Tuolumne water as previously estimated is not greater than is possible of attainment with reservoirs at the locations and of the capacities stated.

To maintain a constant city supply of 400 M. G. D. from the portions of the Tuolumne River drainage area above Hetch Hetchy Valley, Lake Eleanor, and Cherry Valley through periods like 1897–1900 without interference with the rights of the irrigation districts requires storage capacity of 560,000 acre-feet.

To provide for more critical periods than that of 1897–98, an increase of 50 per cent in storage capacity has been estimated necessary. Reservoirs for this additional capacity may be so located that they may be filled only by several years' run-off, since they need be drawn upon only during the dryest periods, such as have been experienced but once since rainfall records have been kept in California, or since 1849.

It may be noted here that a reservoir at Hetch Hetchy 280 feet deep (dam 310 feet high) would afford the necessary storage for 200 M. G. D., including the necessary reserve of 33 per cent for the dryest years.

To summarize: It appears from the foregoing discussion that for periods like 1897–1900:

First. The irrigation requirements of the Turlock and Modesto irrigation districts may be provided by their existing rights if conserved by means of 370,000 acre-feet of storage capacity.

Second. Four hundred M. G. D. may be supplied San Francisco from the high areas without interfering with Turlock and Modesto rights with 560,000 acre-feet of storage.

Third. The combined requirements of San Francisco, the Turlock and Modesto districts, and 240 square miles additional irrigable area may be supplied from the entire flow of the river with 750,000 acre-feet of storage, excepting only the year 1898, when there would have been a shortage of 28 per cent in the estimated quantity of water which may be desired for irrigation of this greatly increased irrigable area. The occurrence of years with so light rainfall as 1898 is so infrequent that the works necessary to avoid the losses consequent upon such a shortage would not be economically justified. There will, therefore, be no injury to the irrigation interests by taking a city supply from this region, provided there can be found reservoir sites affording sufficient capacity; and in any event there will be no infringement of existing rights of the irrigation interests.

There are greater possibilities for storage on the Tuolumne than on any of the rivers to the north within a reasonable distance of San Francisco. This fact offsets, so far as desirability as a source of water supply goes, the lighter precipitation on its watershed and the large prior appropriation of its stream flow.

Below is a list of reservoir sites which have been surveyed, with heights of dams and corresponding estimated capacities, and showing also the portions of the total capacity that could be utilized for equalization of the run-off in excess of prior rights from tributary drainage areas during a period like that from 1896 to 1901, including the exceptionally dry season of 1897–98. The excess capacity in each case could be filled only by diversion of water from other catchment areas or during seasons (in some cases several) of exceptionally high run-off, after which it would be available and should be held for the very exceptional dry years, such as have been estimated as possibly worse than 1898.

The maximum height of dam shown in the list is 325 feet. In none of the schemes for supply for which estimates of cost have been made has a greater height been used. The Shoshone Dam (in Wyoming) is 326 feet high (depth of impounded water, 243 feet), but the gorge in which it is located is very narrow (175 feet at crest of dam), with a resulting small cubical content of masonry per unit of storage capacity. The 325-foot height of dam at Hetch Hetchy is given for comparison with the reservoirs on the Mokelumne, where scarcity of reservoir sites makes great height necessary, although the sites there are not favorable for economical storage.

The list of reservoirs is separated into two parts:

First. Those which are on drainage areas tributary to Hetch Hetchy and Cherry Valleys and Lake Eleanor, and which might become available for either a city water supply or for irrigation. These make up over 80 per cent of the total capacity.

Second. Those on other tributaries of the Tuolumne, which could not be advantageously used in connection with the city supply now projected by San Francisco.

Tuolumne River reservoir sites.

Site.	Height of dam.	Capacity (acre-feet).		Total capacity (M. G.).
		Total.	Utilizable, 1896–1901.[1]	
On Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds:	*Feet.*			
Hetch Hetchy	325	344,000	344,000	112,000
Kibbie Lake	40	3,300	3,300	1,100
Lake Eleanor	245	265,200	207,200	86,500
Cherry Creek—	150	56,800		18,500
Cherry Valley				
Big Lake	30	2,600	2,600	850
Buck Meadow	30	3,000	3,000	1,000
Emigrant Lake	60	14,300	14,300	4,650
Louse Canon	100	9,900	9,900	3,200
Huckleberry Lake	100	52,200	19,700	17,000
Falls Creek—				
Vernon Lake	125	47,900	42,700	15,600
Wilmer Lake	115	5,800		1,900
Tilden Lake	120	27,800	8,300	9,100
Tuolumne Meadows	75	43,200	43,200	14,100
Lake Benson	160	53,800	39,400	17,500
Poopenaut Valley	235	52,100	52,100	17,000
Total	.....	981,900	789,700	320,000
Outside Hetch Hetchy, Lake Eleanor, and Cherry Valley watersheds:				
Errarras Meadow	40	1,100	All.	370
Bells Meadows	60	6,300	All.	2,100
Coffin Hollow	35	2,200	All.	730
Hull Meadow	100	8,000	All.	2,600
Dallas and Warner Lake	.....	60,000	All.	19,500
Davis	.....	48,000	All.	15,600
Dickinson	.....	60,000	All.	19,500
Bradfords	.....	40,000	All.	13,000
Rock Creek	.....	5,000	All.	1,600
Total	.....	230,600	230,600	75,000
Grand total	.....	1,212,500	1,020,300	395,000

[1] See p. 110.

The number of reservoirs in the second part can doubtless be increased considerably, since the character of the drainage area is not an important matter in connection with storage for irrigation, and other sites well down in the foothills, if found to exist, could be utilized.

It is evident, therefore, that after making allowance for such reservoirs as may be too uneconomical to consider seriously, the total utilizable capacity of reservoirs will amount to at least the 750,000 acre-feet, found necessary for a city supply of 400 M. C. D. (see p. 107, and fig. 18) and to meet the full needs of the irrigable lands through a period of years like those from 1895 to date, excepting only 1898, 1908, and 1912. Possibly the much greater capacity that would have been needed for full irrigation in 1908 and 1912 could be obtained. In this connection it should be noted that for irrigation purposes a larger portion of total reservoir capacity than shown could be used, as in computing the utilizable capacity of high reservoirs, deductions from run-off were made for the appropriations for the irrigation districts.

Many sites have been suggested for reservoirs on the Tuolumne above Hetch Hetchy, but with very few exceptions these have been practically on the crests of the divides separating the Tuolumne from adjacent streams and have so little catchment area above them

that, even though they might be given a considerable capacity, very little of it could be utilized and their value is negligible.

Before the reconnoissance survey of July, 1911, was made it was through that the few sites suggested, after a study of the topo-

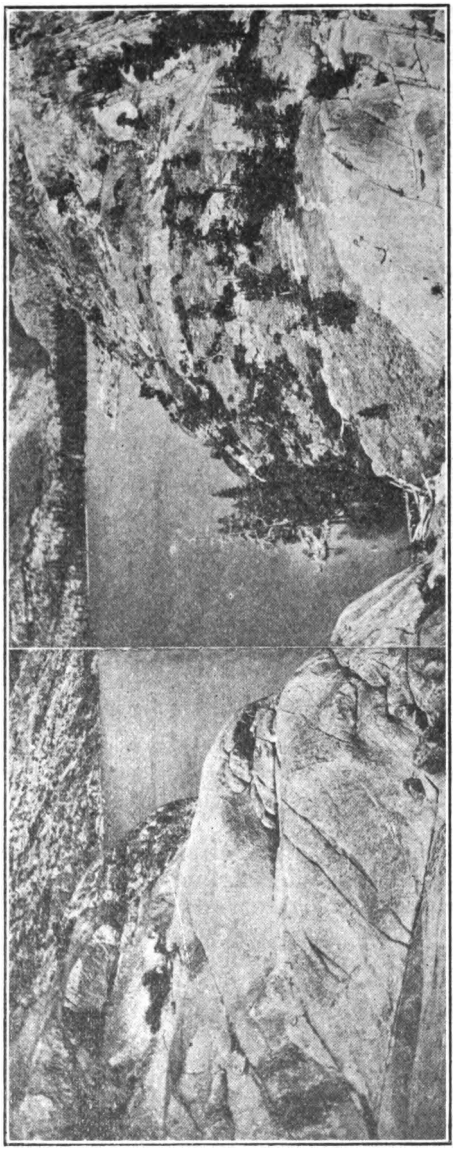

FIG. 19.—View of Lake Benson.

grapical sheets of the United States Geological Survey, in my preliminary report of April 8, might possess considerable merit, and that the capacity at Tuolumne meadows might be greatly increased over that given in United States Geological Survey reports.

As a result of the reconnoissance of these sites, Matterhorn and Virginia Canyons were eliminated from the list, the capacity at Tuolumne Meadows remains as given by United States Geological Survey, and that at Lake Benson is much greater than had been assumed.

It was found that a dam below the Lower Tuolumne Meadows, which would be founded on solid glaciated granite, would have to be 240 feet high, and about 1,800 feet long, to flood the upper meadows to the same depth as the four dams aggregating 2,345 feet in length, but with a maximum height of only 75 feet. The additional storage which the lower meadows would afford would not justify such a structure.

The examination of Matterhorn Canyon, the floor of which is at about elevation 8,500, and above which there is a catchment area of 14 square miles, showed a possible storage of about 80,000 acre-feet with a dam 250 feet high above the creek bed at the only possible dam site. On one side of the canyon at this point there have been great slides or falls of rock from the canyon walls that tower to a height of several hundred or a thousand feet. The width between solid walls of rock at the level of the stream bed may be from 300 to 400 feet instead of only from 25 to 40 feet as it would at first appear.

The examination of Lake Benson, elevation 8,000 feet, catchment area 31 square miles, showed a site suitable for a dam 150 feet high. The corresponding reservoir capacity is about 53,800 acre-feet. There has since been obtained from the engineer of the Turlock irrigation district a map of survey of this lake made by him for a reservoir with a dam 100 feet high and a capacity of 30,600 acre-feet.

The attempted examination in June, 1911, of Poopenaut Valley, immediately below Hetch Hetchy, was very unsatisfactory on account of the high stage of the river, which made crossing the valley at any point impossible.

A survey of Poopenaut Valley was made by the city engineer in September, 1911, for a reservoir with water surface 150 feet above ground level near dam site (requiring a dam 210 feet high).

Mr. Freeman proposes an ultimate extension in height of this dam, increasing depth of impounded water to 225 feet and making the available storage 17,000 M. G., or 52,100 acre-feet.

Many of the reservoir sites in list on page 111 would be very uneconomical to construct, both on account of their location and of quantity of material required for dams per million gallons of water stored. Some of them, on account of limited drainage areas, would be valuable only to provide storage for the very worst years, as it would take several years to fill them.

It will be shown further on that a reservoir at Hetch Hetchy Valley would afford by far the most economical storage of any of those in the above list. It should be noted that its capacity is over 28 per cent of the aggregate capacity of the 25 reservoirs named above and 34 per cent of the capacity of these reservoirs, utilizable for the period 1896–1901. Without its being eventually utilized as a reservoir the future needs of irrigation and of a city water supply as discussed above evidently can not be provided for.

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Reference to the general mass diagram (fig. 18) shows that after conserving all the water possible with the great storage capacity assumed to be possible, there would have been an unavoidable waste each season since 1896, except 1898, 1899, 1900, 1902, 1908, and 1912. Some years the waste would have greatly exceeded the possible use, even with all the storage capacity noted. The run-off for the season 1907–8 (September 1 to August 31) exceeded that of the season 1897–98 by over 10 per cent and was both preceded and followed by seasons of large waste.

It is evident that the period from 1896 to 1901 is the most critical one for which there are run-off records. Estimates of yields of catchment areas and of reservoir capacity necessary to conserve them are based on this period.

Then, as in the case of sources of supply from other rivers, an increase of 50 per cent in storage capacity has been assumed necessary for the dryest possible sequence of years that may come. (See discussion, page 78.) The additional capacity will need be drawn upon at such long intervals only that it may be in reservoirs so located that several seasons' run-off from their catchment areas are necessary to fill them.

In the following estimates of quantities of water which may be conserved from several portions of the Tuolumne River catchment area, Eleanor and Cherry Creeks have been taken together, as they are now both in the possession of the city of San Francisco, and, although the six reservoirs on the Cherry Creek catchment area, in the foregoing list, afford insufficient storage for the Cherry Creek waters, the deficiency can be much more than made up at Lake Eleanor, by giving the conduit connecting Cherry Valley with Lake Eleanor a capacity about 75 per cent in excess of that needed to convey to the city the Cherry Creek portion of the total yield from the combined area.

From the mass diagrams (fig. 20), it appears that from the 193 square miles comprising the Eleanor and Cherry Creek catchment areas, 190 M. G. D. may be obtained. Of this quantity 112 M. G. D. would come from the 114 square miles tributary to Cherry Valley and 78 M. G. D. from the 79 square miles tributary to Lake Eleanor. The reservoir capacity on Cherry Creek utilizable for the 1896–1901 period is 89,000 acre-feet, with dam at Cherry Valley 95 feet instead of 150 feet high. A canal (or other conduit) of 200 M. G. D. (310 sec.-ft.) capacity would be necessary to convey to Lake Eleanor water for which there is not storage capacity on Cherry Creek, as shown by the diagram for Cherry Creek alone.

The total storage capacity needed is 260,000 acre-feet, or, for worst period, 390,000 acre-feet. These capacities could be made up as follows:

	Utilizable 1896–1901.	Needed for worst periods.
	Acre-feet.	*Acre-feet.*
Cherry Valley	39,500	39,500
Five other reserviors on Cherry Creek	49,500	82,000
Kibbie Lake	3,300	3,300
Lake Eleanor	167,700	265,200
Total	260,000	390,000

It was suggested by Mr. P. E. Harroun at the hearing before the Secretary of the Interior May 25, 1910, and enlarged upon by Mr. E. G. Hopson, of the United States Reclamation Service, in a report

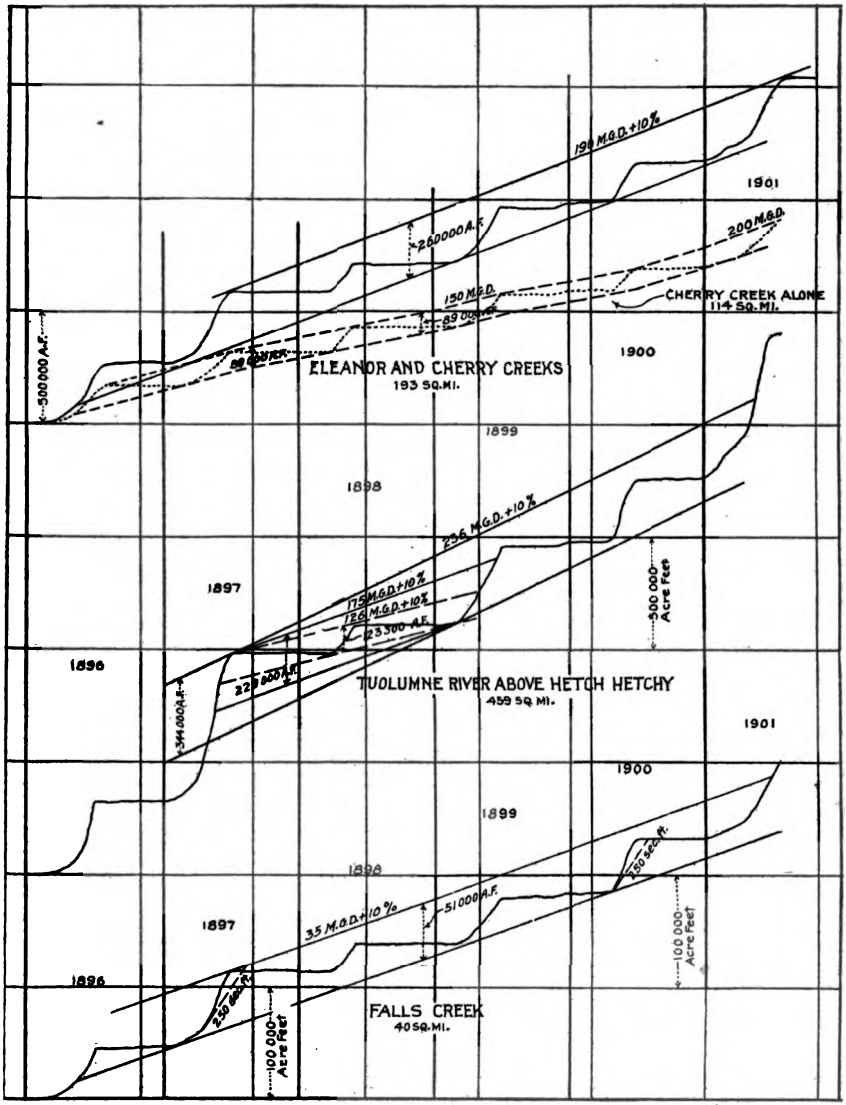


FIG. 20.—Mass diagrams of discharge from portions of Tuolumne River watershed. Eleanor and Cherry Creek diagram shows discharge in excess of that required for Turlock and Modesto rights (total flow at La Grange, up to 2,350 second-feet). Falls Creek and Hetch Hetchy diagrams each show discharge in excess of Turlock and Modesto rights, excepting so much of this excess as is allotted to Eleanor and Cherry Creeks. (As per upper diagram.)

to the Secretary, under date of November 23, 1909, that the run-off from other near-by tributaries of the Tuolumne might also be combined with Lake Eleanor, viz, Falls Creek, which flows through Jack

Main Canyon and Rancheria Creek, which receives the water from Stubblefield and Kerrick Canyons.

The mass diagram for discharge from the 40 square miles of Falls Creek drainage area above Lake Vernon shows that 35 M. G. D. may be obtained here. The necessary storage capacity may be secured on the catchment area, thus:

	Utilizable 1896–1901.	For worst years.
	Acre-feet.	*Acre-feet.*
Lake Vernon	42,700	48,700
Wilmer Lake		
Tilden Lake	8,300	27,800
Total	51,000	76,500

The same quantity of water may be conserved from this watershed by giving the Lake Vernon reservoir a capacity of only 15,000 A. F., constructing a conduit of 250 second-feet capacity from it to Frog Creek, above Lake Eleanor, and providing the balance of the necessary storage (36,000 A. F. for periods like 1896–1901) by raising the height of Lake Eleanor Dam 25 feet, or to a total height of 270 feet. Then the reserve storage for extreme conditions could be located at either Tilden or Vernon Lakes.

The capacity of Wilmer Lake is small and storage there extremely uneconomical.

If the water were to be withdrawn from Falls Creek via Lake Eleanor, instead of allowing it to enter the main Tuolumne and then picking it up again at head of conduit to the city, near the mouth of Cherry Creek, the second plan mentioned would be the more economical as a large portion of the conduit from Lake Vernon to Frog Creek would be in tunnel and nothing in cost would be gained by making it of less capacity than 250 second-feet.

The advantage of taking the discharge of Falls Creek via Lake Eleanor is the increase in power that might be developed from it at the upper or North Mountain power plant, near mouth of Cherry Creek of the city's project, for development under the Garfield permit.

The disadvantage would be the total extinction of Wapama, or Hetch Hetchy Falls (on Falls Creek) which by many would be considered a greater detriment to the beauty of the park than the conversion of Hetch Hetchy Valley into a lake.

To utilize the discharge from the 45 square miles of area tributary to the point on Rancheria Creek from which it would be conveyed to Lake Eleanor requires, according to surveys made by the city engineer of San Francisco, a tunnel 22,470 feet long from Rancheria to a point on Falls Creek between Brannigan and Vernon Lakes, and one 15,200 feet long from Falls Creek to Frog Creek. The second tunnel would be used also for Falls Creek water as described above.

No reservoir sites have been located or suggested on branches of Rancheria Creek, consequently all the water that can be used is so much of the discharge of the creek in excess of that which must go to satisfy prior rights, as can be carried by the tunnel.

A tunnel of 250 second-feet capacity would be in use to its full capacity about two months and would have been empty for from five to nine months each year of a period like 1896–1901.

It would have saved 75 per cent of the available discharge and this, with a storage capacity of 36,000 A. F., for the period named (or 54,000 A. F. for the dryest time), which could be supplied only at Lake Eleanor, would permit a constant draft of 30 M. G. D.

With Rancheria Creek depending on Lake Eleanor for storage, the reservoirs on Falls Creek would have to be used for Falls Creek waters and even then the height of Lake Eleanor Dam would be still further raised to 275 feet, when its total capacity would be 319,200 A. F. The canal or tunnel from Falls Creek to Frog Creek would then need a capacity of 300 second-feet.

For the purpose of comparison, both as to quantity of a safe dependable supply of water, and cost of same, that may be obtained from the watershed that is, and that may be made, tributary to Lake Eleanor, corresponding figures for the drainage area tributary to Hetch Hetchy are given.

If water passing through Hetch Hetchy Valley were to be used for a city supply, whether or not that valley were to be used as a reservoir, there would be no object in diverting Falls and Rancheria Creeks to Lake Eleanor except to develop additional power and to take advantage of surplus storage capacity there. We have seen that Falls Creek waters may be conserved in their own drainage basin. Therefore, these areas are included, in the deductions which follow, with the Hetch Hetchy watershed to which they belong.

Using Hetch Hetchy Valley as a reservoir, with a capacity of 344,000 A. F., as per table on page 111, subsequent to the maximum development of the Lake Eleanor and Cherry Creek area, a daily draft of 236 M. G. would be possible through a period like 1896–1901. To support this draft through the worst possible period the necessary 50 per cent additional reservoir capacity could be secured at the four sites, Lakes Benson, Vernon, and Tilden, and Poopenaut Valley.

Were this system to be developed before Lake Eleanor the daily supply would be increased from 236 M. G. to 310 M. G. This is because all of the discharge of Eleanor and Cherry Creeks could be used to supply prior appropriations before any water need be released for that purpose from Hetch Hetchy.

The dependable yield from the watersheds tributary to Lake Eleanor, Cherry Valley, and Hetch Hetchy Valley, without infringing on the rights of the irrigation districts is seen to be 190 M. G. D. from Eleanor-Cherry watershed and 236 M. G. D. from Hetch Hetchy watershed, or if Hetch Hetchy supply were developed first, 310 M. G. D. from that source and 116 M. G. D. from Eleanor-Cherry; the total being 426 M. G. D. The total depletion of storage would be for the 1896–1901 period, 604,000 acre feet.

Compare with this result, Mr. Cyril Williams's conclusion, that the same watersheds, through the same period would yield a safe supply of 427.7 M. G. D. with a depletion of storage amounting to 610,000 acre feet (198,500 M. G.).

Making Hetch Hetchy the only reservoir for a city supply on the catchment area and allowing one-third of the total capacity of 344,000 A. F., as a surplus for worse periods than 1896–1901, there would then be a daily supply of 175 M. G., or if this reservoir were given priority over Lake Eleanor in the use of run-off, 248 M. G.

The combined capacity of all the reservoirs on the Hetch Hetchy catchment area, except Hetch Hetchy itself, together with the discharge. in excess of the irrigation rights, would yield 138 M. G. D.

through all seasons, assuming, as before, that the Eleanor-Cherry watershed were first developed to the limit of 190 M. G. D.

The question as to the necessary restriction in the use of Yosemite National Park by visitors and campers, which has been the cause of much of the opposition to the use of the park as a catchment area for water supply, is discussed by Mr. Allen Hazen, consulting engineer, in a report dated December 4, 1911, to the city engineer of San Francisco, a copy of which has been furnished you.

Mr. Hazen says: "No modification of or addition to the rules—now in effect—need be made." This subject is given much attention in Mr. Freeman's report of July 15, 1912.

At the hearing before the Secretary of the Interior, November 25, 1912, it was clearly brought out that the restrictions which would necessarily be imposed upon campers for the protection of other campers within the park would be abundantly sufficient for the protection of users of the water after it has passed through the reservoir and the aqueduct to San Francisco.

13. San Joaquin River.—The elimination from further study of the San Joaquin River as a source of water supply for San Francisco was requested by the city engineer in a letter to the board under date of August 5, 1910, for reasons, in addition to those advanced at the same time for the elimination of the Sacramento River (viz, that filtration of the water would would be necessary, and the city was seeking pure rather than purified water), as follows: "That if drawn upon within the limits of tidal action brackish water will probably be drawn into the intake during low stages, and if drawn from above this limit the supply, by reason of increasing draft for irrigation purposes, will prove insufficient."

This request the board at first complied with, but further consideration of the facts that the volume of water in the lower San Joaquin and its several branches is so immense and is fed by outlet sloughs from the Sacramento and the San Joaquin above the points where brackish water has been found, so far as is known, and that although the extensive use of the San Joaquin water for irrigation has reduced the summer flow at points a short distance below the points of diversion to a negligible quantity, a considerable portion of this water seeps back into the river, and that this quantity will increase as stored water is more extensively used during the low water period, led to the San Joaquin being restored to the list of those sources that should be investigated.

[Extract from the report of Col. Mendell, to San Francisco Water Commission, Aug. 6, 1877.]

The effect of the abstraction of large volumes of water from the rivers—for the purpose of irrigating adjoining lands—on the flow at points a few miles below the diversion is discussed at some length in the report of the United States Commissioners of Irrigation, published in 1874. The experience in Italy and India, as observed and discussed by their ablest engineers, seems to dispose of this portion of the subject in a thorough manner by proving that the water is returned to the river in so large proportion that the quantity a few miles below seems to be undiminished, either absolutely or only in small degree.

[Extract from report of Prof. Hyde to Spring Valley Water Co., on the San Joaquin River, as a source of water supply.]

Studies made by the United States Department of Irrigation investigations in Colorado indicate that when irrigation in a given district has been sufficiently long established to satisfy the ground storage capacity the total yield by seepage to the streams draining such irrigated areas will amount to perhaps 30 per cent of the total volume of water used for irrigation.

It is understood that water taken from the San Joaquin must be purified.

The Spring Valley Water Co. considers that when all its resources on the peninsula and on the Alameda Creek watershed are exhausted it can greatly increase its supply by pumping from the San Joaquin to its natural filter beds in the Livermore and Sunol Valleys. Through the courtesy of the Spring Valley Water Co. access has been had to a report of 200 pages on such a supplemental supply, by Prof. Chas. Gilman Hyde. By utilizing the great storage possibilities of reservoir sites held by the Spring Valley Water Co., on the Alameda Creek watershed, it is apparent that pumping from the river could be discontinued during the low-water stage, forced at other times, and a supply of perhaps several hundred million gallons daily maintained from the reservoirs.

The mass diagram (fig. 21) shows discharge of the San Joaquin River at Southern Pacific Railway bridge, near Lathrop, since 1898, as determined by Prof. Charles G. Hyde from record of gage heights, reduced by the amount of water appropriations of several irrigation districts in excess of the actual quantities diverted and with allowance made for the return of portions of such diverted water by seepage, as per statement on the diagram. The resulting diagram is intended to show the discharge as it would be with irrigation in progress as allowed for through a similar series of years. The record of gage heights runs back several years prior to 1898, but the record for that year, which is known to be the lowest since 1876, is entirely missing.

Actual flows were measured under the direction of Prof. Hyde at comparatively few stages, the flow at other stages being determined by interpolation and exterpolation. The results, therefore, can not be relied upon as very accurate.

The lowest recorded flow of the San Joaquin River at this point is said to have been 230 second-feet, probably in 1898. In November, 1905, it was 300 second-feet. In 1905 the mean monthly flow after August did not exceed 500 second-feet. The smallest annual discharge since 1898 was in 1908, as shown by the diagram.

A full development of irrigation needs by means of mountain storage to the extent shown by the middle diagram for the year 1908 would result in a large seepage back into the stream but such a contingency is too remote and uncertain to figure on.

The diagrams show that to maintain a draft of 200 M. G. D. through the year 1908 a storage capacity of 30,000 M. G. would be required. This equals 92,000 acre-feet, or a depth of 7.2 feet, over 20 square miles of reservoir surface. It is evident, therefore, that such a draft could not be maintained from any point on the lower San Joaquin or Old River without getting salt water to the intake were it not that the Sacramento River also contributes water to the lower San Joaquin.

Confining ourselves, for the present, to San Joaquin water only: The 30,000 M. G. storage required is a 150-days' supply of 200 M. G. D. It is known that the 1898 flow was less than that of 1908, and other years may have been and may be even worse, so that draft from storage for at least 180 days, and probably for 250 days, should be provided for.

If such storage were to be provided for in the Alameda Creek watershed, it would mean that to supply San Francisco with 200 M. G. D. pumps and conduits from the San Joaquin River to Alameda Creek of

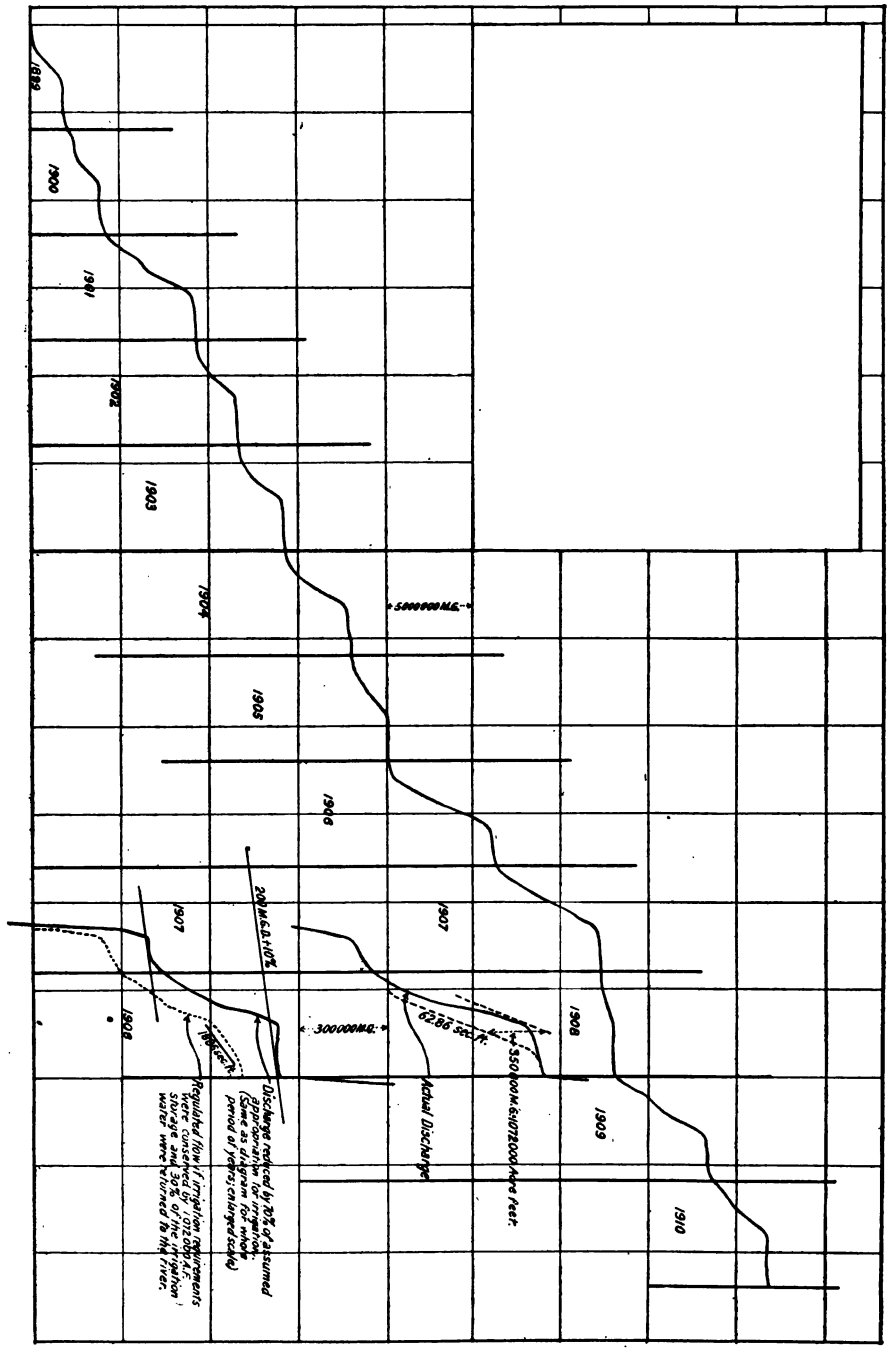


FIG. 21.—Mass diagram of discharge of San Joaquin River at Southern Pacific Railway bridge near Lathrop, using mean monthly rates of flow as given by Charles Gilman Hyde in his report of January, 1911, to the Spring Valley Water Co., with deductions of 70 per cent of such portions of present and of prospective future appropriations of water for irrigation purposes as were not actually diverted from the river or its tributaries. The resulting diagram shows the volume of water that, under the assumptions given as to appropriations and seepage back to the stream, would pass this point during a similar term of years. Additional information regarding this diagram is given on page 121.

400 M. G. D. capacity would be needed under the assumed necessity of 180 days' storage, or of 635 M. G. D. if draft would have to be from storage only for 250 days.

In fig. 21 the appropriations assumed and allowed for are as follows:

	Second-feet.
Turlock irrigation district, total	1,500
Used since 1898, 1,000 second-feet.	
Modesto irrigation district, total	850
Used since late in 1903, 600 second-feet.	
Patterson ranch	
South San Joaquin district	1,700
Other districts, unallowed for above	2,236
Total	6,286
Deduct 30 per cent returned to stream	1,886
Leaving total deduction from natural flow	4,400

The amount deducted from the flow was less than this by the quantity actually diverted.

In computing quantities for the mass diagram, 3,800 second-feet was deducted for each month from April to September, inclusive, and one-half that quantity for March and October for the years 1899, 1900, 1901, 1902, and part of 1903; 3,200 second-feet and one-half that amount, was deducted for the corresponding months of the years 1904, 1905, 1906, 1907, 1908, 1909, and the latter part of 1903; 3,000 second-feet, and one-half that amount, was deducted from the corresponding months of 1910.

It has been shown before that all the storage capacity of sites controlled by the Spring Valley Water Co. on Alameda Creek watersheds is needed for the conservation of Alameda Creek waters unless sites claimed by the Bay Cities Co. and other interests are also used for the latter purpose.

To use the Peninsula Reservoir excess capacity for San Joaquin water would require the same excess capacity of conduits as above all the way from the river to Crystal Springs Reservoir. This would be prohibitive in even greater degree than the duplication of pipes to Alameda Creek.

It appears from the above that any scheme for supplying filtered water from the San Joaquin River would have to depend on the inflow to the lower reaches of that river of Sacramento River water, and therefore the nearer both to that river and to the point of delivery the pumping station could be located (and still be kept above points possibly reached by salt water) the better.

A point on Old River, known as Clifton Court, seems the most favorable location. The mouth of Old River, in the main San Joaquin, is above the mouth of the Mokelumne River and of Georgiana, Seven Mile, and Three Mile Sloughs, which carry Sacramento River water to the San Joaquin.

From its mouth to Clifton Court, Old River channel is about 30 miles long. This distance could be considerably shortened by cut-offs, if found desirable.

The cross section of Old River near Clifton Court at low water measures about 2,300 square feet and is apparently great enough at all points so that a draft of 200 M. G. D. at times when all the water would have to come from the north, i. e., from the Sacramento, would

not cause a mean velocity of more than 0.2 foot per second. The fall in the 30 miles of channel would not exceed 1 foot.

Estimates of cost of constructing and operating a 200 M. G. D. filtered supply from the lower San Joaquin exceeded those for supplies of equal quantity from any of the mountain sources.

The suggestions made by the Spring Valley Water Co. for the use of the San Joaquin River water in connection with its system is for pumping the water to the Alameda Creek watershed and there to filter it in the natural gravel beds of the Livermore Valley and in the vicinity of Sunol. This is doubtless possible to some extent. Assuming that the entire cost of constructing artificial filter beds and the expense of operating them could thus be eliminated, the total cost of the scheme would be reduced by cost of filtration plant and by capitalized value of operating same. The possible reduction in cost of filtering is partly offset by the loss of head between the point where the conduit crosses the divide above the reservoirs in which the water would need be stored prior to being released to the natural filter beds and the point of recovering the water near Pleasanton or at Sunol. This loss would have to be made up by additional pumping.

The net saving in cost would not give this scheme a pecuniary advantage over the mountain supplies which do not need filtering.

The relative merits of the San Joaquin and Sacramento Rivers as sources of water supply and other disadvantages of the former than those described above are well shown by the following quotations from Mr. Hazen's report previously referred to:

> Sacramento River water is clearly of better quality than San Joaquin water. This is well shown by * * * analyses made by United States Geological Survey. These results show the Sacramento River to be not only much softer and more free from mineral matter, but the seasonal variation is much less.
>
> The Sacramento River water may be filtered so as to produce a good potable water at all seasons of the year, removing the turbidity, color, and the results of sewage pollution. The San Joaquin could be similarly purified, but would contain an excess of mineral matter during a part of the year. A part of this could be removed at greatly increased expense by softening, while other parts could not be so removed.

McCloud River.—The remarkably even flow of this river, as compared with those of other California streams which have been reported upon, is well shown on the mass diagram (fig. 22). It is this feature that renders the construction of large and expensive storage reservoirs in connection with a municipal water-supply scheme, depending on the McCloud River, unnecessary.

The snow banks and glaciers of Mount Shasta, together with the porous lava formation, through which the water from the melting snow and ice (as well as the precipitation on other parts of the watershed) percolate before they emerge as springs, serve as most effective reservoirs in regulating the flow of the McCloud.

United States Geological Survey records of run-off measurements extend back to 1902 only. No record was kept or measurements taken between June, 1908, and December, 1910.

There has been a United States fish hatchery at Baird, about 2 miles above the mouth of McCloud River, for many years. In a letter replying to a request for information as to a possible record of gage heights that it was thought might have been kept by the Bureau of Fisheries, Mr. G. H. Lambson, the superintendent, said that in January, 1911, the river was lower than at any other time

during the 15 years that he had been there and that the oldest residents on the river stated that it was lower than ever known before.

The United States Geological Survey gaging records show a flow in the river at Baird of 1,240 second-feet for a period of five days in January, 1911. On January 4, 1912, the same low stage was again

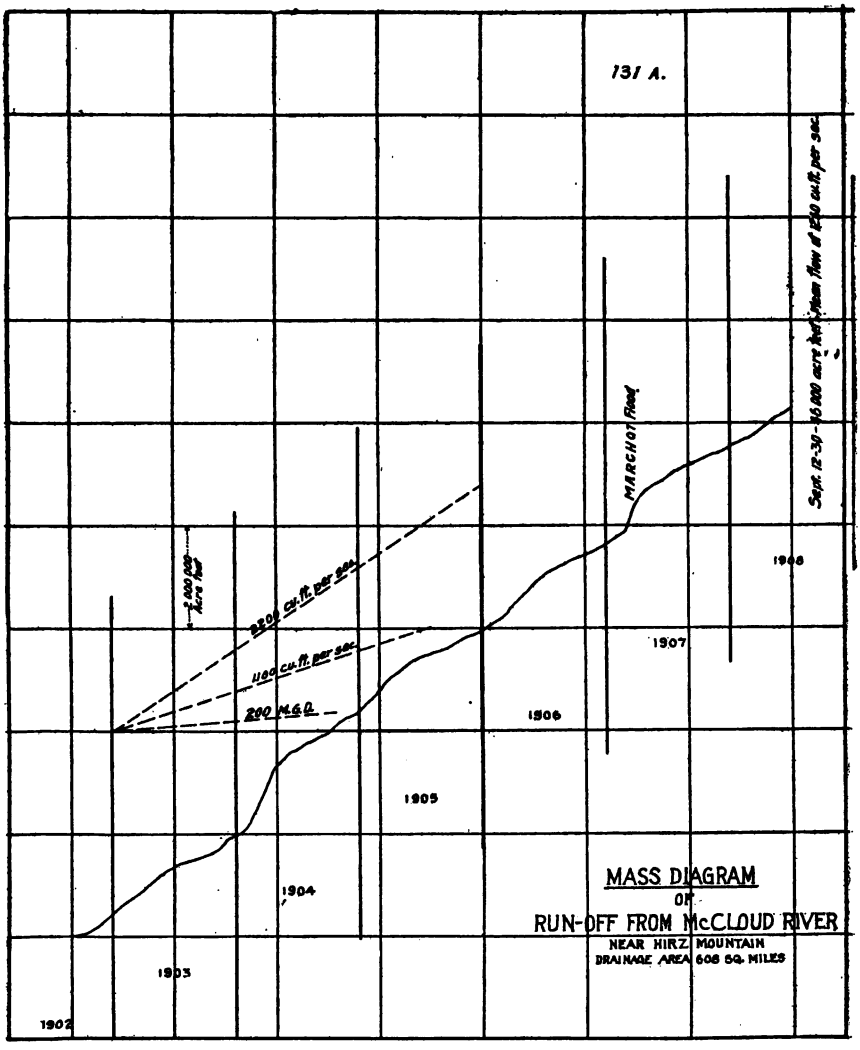


FIG. 22.—Mass diagram of run-off from McCloud River near Hirz Mountain; drainage area 608 square miles.

reached, but the river raised the following day. On September 28 and 29, 1912, the discharge fell to 1,210 second-feet. Since the latter date it has been greater.

The earlier gagings (1902–1908) were at a point about 12 or 15 miles above Baird. A minimum discharge of 1,180 second-feet is recorded. The catchment area above Baird is enough larger than

that above this station to account for a difference in minimum discharge of 30 second-feet (1,210–1,180).

The Weather Bureau records of precipitation for stations in the vicinity of Mount Shasta do not extend further back than 1889. A study of these records indicates that the only period during which a materially smaller flow in the McCloud than in September, 1912, seems probable is that from 1897 to 1899. At Sisson from 1893 to the winter of 1899, six years, the seasonal precipitation was continuously below the normal, and for the season 1898–1899, the last of the series, it was but 40 per cent of normal.

Filings prior to those of the proponents of this project on water for power development and applications for rights of way over public lands have been made. Conflicting rights are still unadjudicated.

There are extensive lumbering operations on this catchment area. There are also some agricultural and dairy interests.

Analyses of the water at Baird show it to be a very pure soft water, and the Government fish culturists have found it particularly well adapted to their uses.

Contamination by sewage from the sawmill town of McCloud will have to be guarded against, though no evidence of such contamination has been noted.

Delivery of the water for San Francisco directly to the Crystal Springs Reservoir (via Dumbarton Point, as for supplies from sources south of American River) would add unnecessarily to the cost. But the peninsula reservoirs and others in Alameda or Contra Costa County would have to be given the greatest possible capacity, to be filled and held in reserve against the contingency of the McCloud River conduit being closed for repairs.

The plan proposed by the Mount Shasta Aqueduct Corporation for a water supply from the McCloud River provides for the delivery by gravity of 400 M. G. D. at an elevation of 300 feet into twin reservoirs, having an estimated capacity of 30,000 M. G., on Pinole and San Pablo Creeks, in the Contra Costa Hills north of Berkeley. From these reservoirs the conduit would have a capacity of 400 M. G. D. to Oakland, thence across the bay to San Francisco 200 M. G. D. Delivery in San Francisco would be at elevation 200 feet above sea level.

The distance to San Francisco from the San Pablo Reservoir is substantially the same as from Crystal Springs Reservoir. The distance to center of Oakland from San Pablo Reservoir is no greater than from Lake Chabot, to which Oakland water would be delivered from the Hetch Hetchy Aqueduct by a branch conduit about 16 miles long.

The route of the proposed Mount Shasta Aqueduct is such that for most of the distance it can be kept very near the hydraulic grade line, thus permitting the use of cut and cover gravity section and reinforced concrete pressure pipe instead of the heavy steel pipe under a head of from 300 to 600 feet for a distance of 40 miles across the San Joaquin Valley, as is the case with supplies from the Sierras east of San Francisco.

Summary of distant supplies.—The following table shows, for each of the sources of supply from which it has been shown that a suitable supply might be made available to San Francisco and the bay cities, the quantity of such supply and the feasible combinations of such supplies to produce a total of 400 M. G. D. or more:

	Supplies needing filtration.	Supplies which with moderate supervision of watershed need no filtration.			
		M. G. D.	Feasible combinations of sources.		
			M. G. D.	M. G. D.	M. G. D.
	M. G. D.				
Eel River		180			
Sacramento River	400+				
Feather River	400				
Yuba River	400	164			
American River		(?)			
American-Cosumnes River		215	215		
Mokelumne River		128	128	128	
Stanislaus River		57	57	57	
Tuolumne River:					
Eleanor-Cherry		190		190	190
Rancheria Creek		30		30	236
Hetch Hetchy		206			
McCloud River		400			
Combination total			400	405	426

If Hetch Hetchy supply were developed before Eleanor-Cherry, 310 M. G. D. might be obtained there, and the total 426 M G. D. subsequently made up by taking 116 M. G. D. from the Eleanor-Cherry watershed.

The map of central and northern California (Pl. I) shows the location of the Tuolumne conduit as proposed by Mr. Freeman, also suggested location of conduits for the sources shown in above table giving over 400 M. G. D. Approximate profiles of several of these conduit lines are shown on Plates II and III.

Except for the Hetch Hetchy and McCloud River Aqueducts the profiles are not of lines which have been proposed by the advocates of the several sources, but are of lines located on topographic maps of the United States Geological Survey with special reference to combining different sources to produce a total of 400 M. G. D.

The following table shows, for each of the sources, or combination of sources, that may be developed to yield 400 M. G. D., the extent of catchment areas and reservoir capacities required for such development. It is assumed that one-half the total supply is delivered on each side of San Francisco Bay.

Catchment area.	Square miles.	Reservoirs. For period like 1897–1901.		For assumed driest period.	
		Number.	Capacity.	Number.	Capacity.
			M. G.		*M. G.*
Tuolumne, including Lake Eleanor, Cherry Valley, Hetch Hetchy Valley, and their watersheds	652	[1] 2	183,000	4	276,000
Eleanor-Cherry		T 8	95,000	8	142,000
Stanislaus	997	S 4	37,000	5	55,500
Mokelumne		M 3	33,000	3	50,400
		15	165,600	16	247,900
Stanislaus		S 4	37,000	5	55,500
Mokelumne-American	1,010	M 3	33,600	3	50,400
Cosumnes		AC 6	42,300	8	63,500
		13	112,900	16	169,400
McCloud	653	2	[2] 30,000		

[1] If the Hetch Hetchy reservoir was not built until after Lake Eleanor and Cherry Creek had been developed to the utmost, there would then have been required 8 reservoirs on Eleanor-Cherry watersheds and the total number required would have been 9 instead of 2.

[2] Reservoirs for sterilization purpose only, and not for conservation of run-off.

COMPARATIVE ECONOMY OF STORAGE AND COST OF DAMS.

The principal item of cost of a reservoir, especially when located on the public domain is that of the dam at its outlet. With few exceptions very little is known about the various dam sites which would be required for the many reservoirs included in the several projects. For the very large dams, and some others, there have been available surveys of the sites sufficiently in detail to permit of estimates of quantities though with but little, if any, knowledge as to

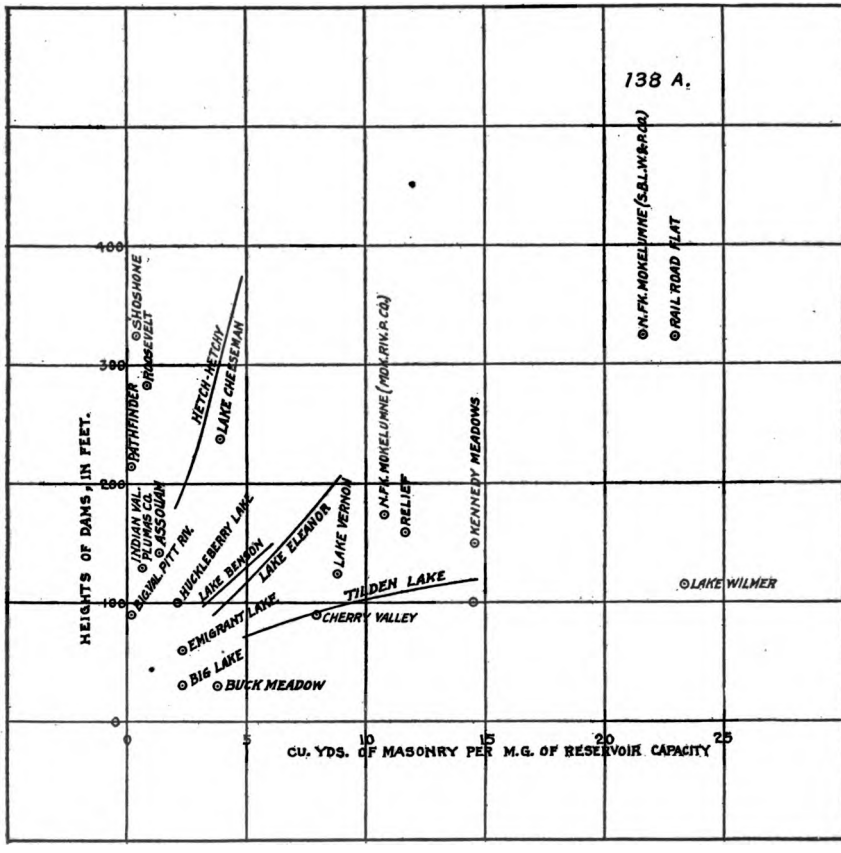


FIG. 23.—Diagram showing quantity of masonry in dams of gravity section and of various heights, per million gallons of water stored in reservoirs. At some of the sites other types of dam have been used or proposed, but relative economy of storage is not greatly affected.

foundation conditions. In some cases the maximum height and length of dam was known but nothing further as to the cross-section of the site. Except where surveys have shown some other type to be more advantageous and where estimates of quantities of materials involved in construction have been made (as is the case with most of the dams in the American-Cosumnes project), a simple gravity section of masonry dam has been adopted for the cost estimates which follow. For those dams of which only the heights and lengths were known, assumption had to be made as to form of cross-section of site. The diagram (fig. 23) shows, for each of several dams, the

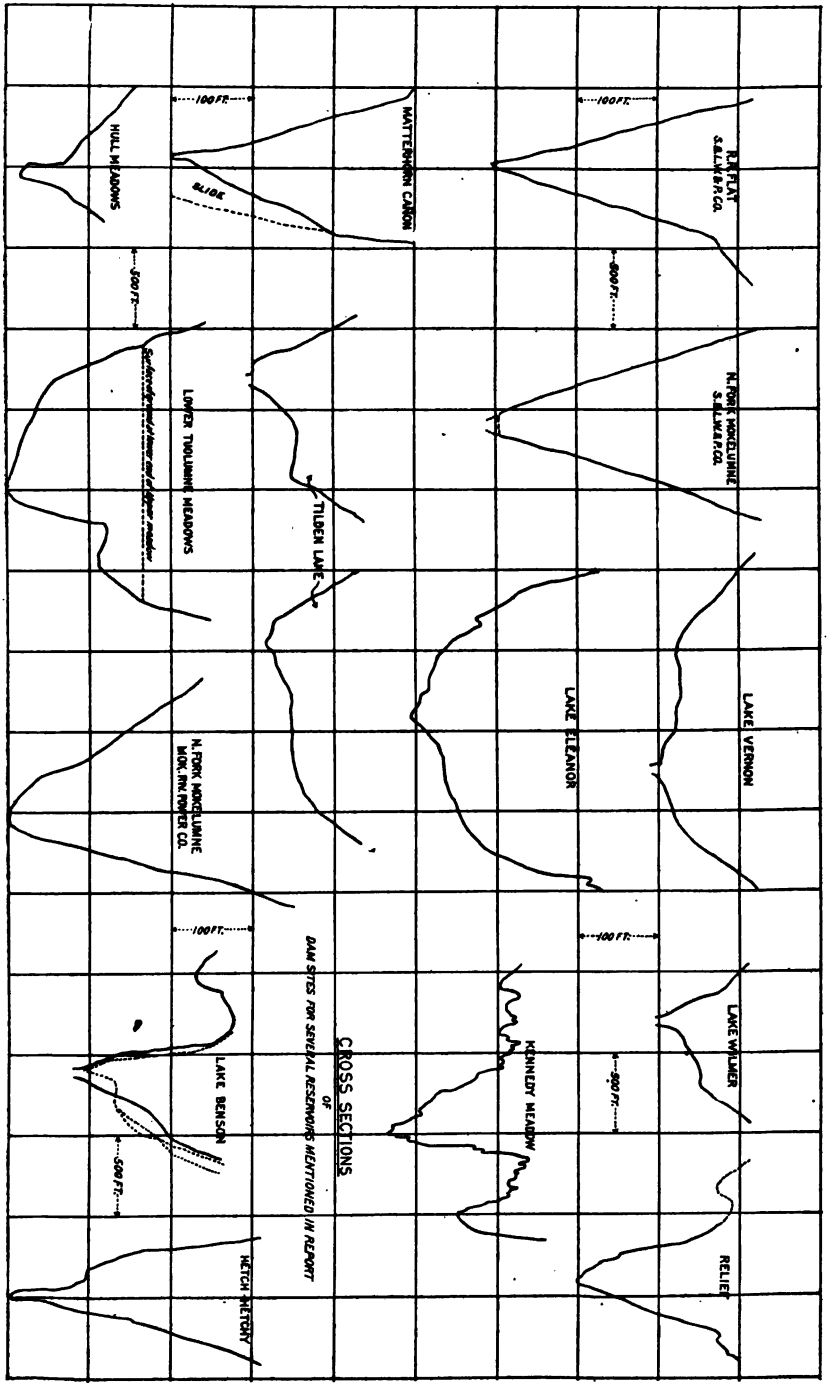


FIG. 24.—Cross sections of dam sites for several reservoirs mentioned in report.

volume of masonry per million gallons of reservoir capacity. Where the capacities corresponding to different heights of dam were known those dams are shown on the diagram by lines instead of by points only.

In many cases solid masonry dams would quite likely not be well adapted to the situation, but it is altogether likely that if sites existed

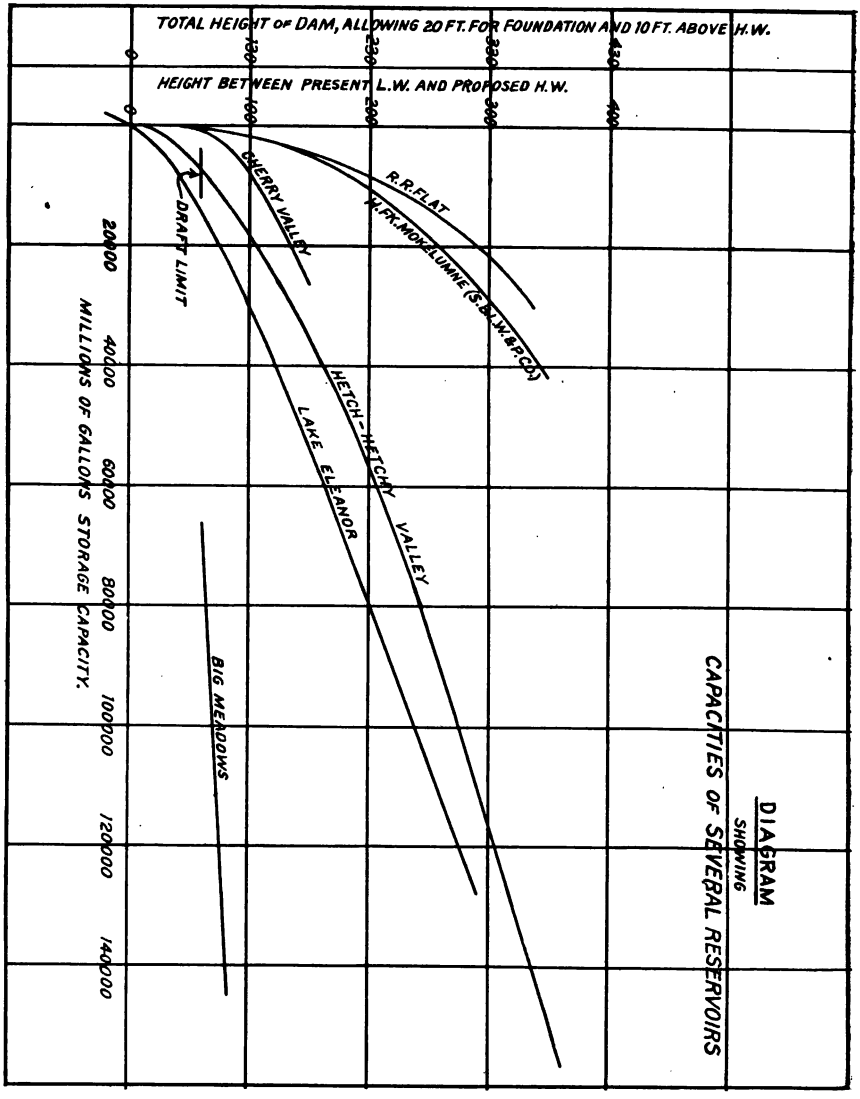


FIG. 25.—Diagram showing capacities of several reservoirs.

where large storage could be effected by arched dams, without gravity sections, they would have been surveyed and appropriated.

The quantities in a loose rock dam with reenforced concrete or steel curtain wall, or in an earth dam, would be so increased over those of a gravity masonry section as to make the total cost of the

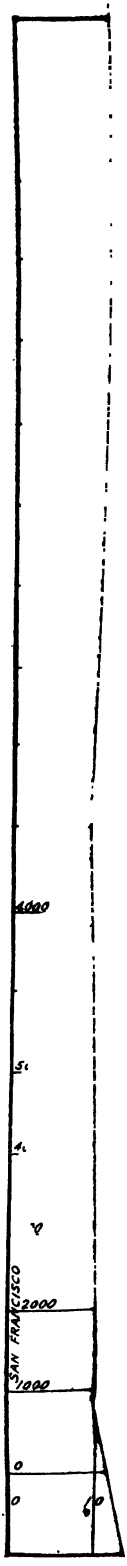
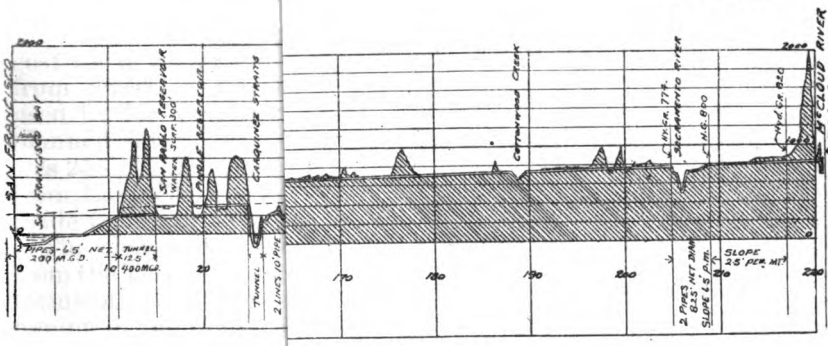


PLATE III.



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former sufficiently near that of the latter as to warrant the assumption made.

For comparison there are also shown on the diagram the relation between volume of masonry and the storage capacity for several large dams which have recently been constructed, viz: Roosevelt, Shoshone, Pathfinder, Assouan, and Lake Cheeseman.

It should be noted here that of all the California reservoirs platted, only that at Hetch Hetchy approaches in economy the five just mentioned, excepting only Indian Valley on the Feather River in Plumas County and Big Valley on the Pit River in Lassen and Modoc Counties. Reservoirs at these last-mentioned sites would flood over 12,000 and 50,000 acres, respectively, of land, partly choice agricultural land under cultivation. It is possible that they may sometime be used to increase the low-water flow of Sacramento River, but they can hardly be considered available in connection with San Francisco water supply.

BASES OF COST ESTIMATES.

My preliminary report of March 20, 1912, contained estimates of cost for development of water supplies and construction of conduits from several watersheds to San Francisco, based on the unit costs used by Mr. Grunsky and Mr. Manson for the Tuolumne project as planned several years ago. The maximum supply estimated upon was 255 M.G.D., which quantity it has been shown could be obtained from Lake Eleanor and the watershed which is and which could be made tributary to it (including the diversion of Falls Creek).

The change in the city's project for the development of a supply from the Tuolumne River from one of 200 M.G.D., involving the generation of electric power in the Sierras and a pumping plant near Altamount in the Coast Range, to a 400 M.G.D. gravity supply, leaving the possible power development a matter for the future, although recognizing that the value of such power should be credited to the scheme, compels a complete revision of the cost estimates. The chapters on power and pumping plants and transmission lines are eliminated.

The following estimates are based on Mr. Freeman's unit costs, with all the overhead charges included.

For the Hetch Hetchy project the figures are a rearrangement of Mr. Freeman's estimate, so far as the cost of development is given in his report of July 15, 1912.

For the features of the Mount Shasta Aqueduct which have no counterpart in the Hetch Hetchy scheme, liberally high unit costs have been assumed.

For the Sacramento River filtered supply, Mr. Hazen's estimates have been used except for conduits. Tunnels and pipe lines of the dimensions used by Mr. Freeman for the Hetch Hetchy Aqueduct have been estimated upon.

These, with the same pumping lifts used by Mr. Hazen, permits delivery in San Francisco at an elevation of 140 feet above sea level instead of about 20 feet as per Mr. Hazen's plan. This greatly reduces the amount of pumping necessary in San Francisco, but the delivery would still be at an elevation of 60 feet less than for the gravity supplies proposed.

In making these estimates the dates on which successive installations are considered necessary are not those given on page 70, which would be required after local supplies had first been developed to the extent shown on page 70, but are the dates on which it has been assumed it would be most economical to bring in the outside supplies.

These dates are as follows: 100 M. G. D. by 1920, 140 M. G. D. by 1940, 200 M. G. D. by 1960, 285 M. G. D. by 1980, 400 M. G. D. by 2000.

ESTIMATES OF COST.

The Hetch Hetchy project.

For 160 M. G. D. Early intake to San Francisco:	
Tunnels (400 M. G. D. capacity)—	
10 feet diameter, 142,780 feet, at $52 (maximum, $55.10)	$7,427,400
12.8 feet diameter, 215,010 feet, at $66.50 (maximum, $70.40)	14,291,200
Pipe lines (cement lined and coated)—	
6.75 feet diameter, shell varying from ¼ to ½ inch in thickness, price per foot from $15.40 to $25.60—	
95,180 linear feet	2,277,200
Pipe under San Francisco Bay, 4,880 linear feet, at $98.20	479,000
7.75 feet diameter shell, varying from ¼ to 1⅛ inch, and price per foot from $17.23 to $39.10, except short siphons much higher—	
237,930 linear feet	8,201,100
Pipe under San Joaquin River, with all connections, 430 linear feet	236,000
9 feet diameter, shell, 5/16 to ⅝ inch, price per foot from $22.40 to $40.85, 4,700 linear feet	131,000
10 inches diameter, shell, 7/16 to 1 7/16 inch, price per foot, $43.36 to $89.75, 4,000 linear feet	246,600
Concrete arches, to carry siphon across main Tuolumne and South Fork—	
900 feet, at $69	62,000
200 feet, at $85	17,000
Hetch Hetchy Reservoir—	
Low dam, with appurtenances, 90,400 cubic yards concrete	1,315,500
Construction road with temporary railroad	1,288,100
Scenic road, Hetch Hetchy Reservoir	444,500
Connection—	
Crystal Springs, Millbrae pumps	916,800
Early intake	168,000
Total for 160 M. G. D. from Early intake to San Francisco	[1] 37,501,400
For 80 M. G. D. additional, including extension of aqueduct from Early intake to Hetch Hetchy and branch from Irvington gatehouse to Lake Chabot Reservoir:	
Tunnels, Early intake to Hetch Hetchy—	
10 feet diameter, 61,800 linear feet, at $55.50	3,428,700
8 feet diameter, Hetch Hetchy to Lake Eleanor, Cherry Valley, 35,900 feet, at $31.35	1,124,400
Reservoirs—	
Lake Eleanor temporary dam	662,000
Cherry Valley	600,000
Eleanor, Cherry Creek water rights	1,070,000
Poopenaut dam and reservoir	898,100
Lake Chabot Aqueduct—	
72,880 feet tunnel, 10 feet diameter, at $54	3,935,000
8,980 pipe siphons, 6.75 feet diameter, 7/16 to ⅜ inch shell	359,400
Connection, Millbrae pumps to San Francisco	913,400
Crystal Springs, by-pass	919,800
Total for 240 M. G. D. supply	51,412,200

[1] This amount is about $600,000 greater than given by Mr. Freeman for same stage of development, due principally to his use of certain less expensive works that do not enter into the greater project for which estimates are given.

The Hetch Hetchy project—Continued.

For 160 M. G. D. additional:	
Duplication of pipe line across San Francisco Bay	$2,756,200
Duplication of Alameda Creek siphon	131,000
Duplication of San Joaquin Valley pipe line	8,437,100
Duplication of siphons on Lake Chabot Aqueduct	359,400
Extension of Hetch Hetchy Dam to final height	[1] 1,840,500
Permanent dams at Lake Eleanor, at Poopenaut Valley, and on Cherry Creek	[1] 9,220,000
Enlargement of Lake Chabot reservoir	3,211,000
Grand total of construction costs for 400 M. G. D. supply	[1] 77,367,400
First installation, 160 M. G. D. capacity, all required by 1947, cost (time of construction, 1914–1920; mean date, 1917)	[2] 37,501,400
Second installation, increasing capacity to 240 M. G. D., all required by 1969, cost (time of construction, 1945–1947; mean date, 1946)	[3] 13,910,800
Final installation, increasing capacity to 400 M. G. D., all needed by 2,000 A. D., cost (time of construction, 1963–1969; mean date, 1966)	[4] 25,955,200
	77,367,400

Time between first and second installations, 29 years.
Time between second and third installations, 20 years.
Amount (S), which if invested at 4½ per cent (=r) compound interest in 1914 will finance the project:

$$S=\frac{A}{(1+r)^3}+\frac{B}{(1+r)^{32}}+\frac{C}{(1+r)^{52}}=\$38,900,000.$$

Power development—		
115,000 H. P. (net) may be developed from the 400 M. D. G. supply at plants on the aqueduct line, requiring installation of power houses and machinery only—		
Estimating cost of these at	$6,000,000	
Value of power at the plants at $20 per horse-power year, or a total value of $2,300,000, per year, capitalized at 4½ per cent	51,100,000	
Net credit to cost of project		45,100,000

NOTE.—If a portion, say, of one-half of this power has to be disposed of at cost, the credit would be proportionately less.

Estimate of cost of constructing and operating filter plant for Hetch Hetchy water, if found necessary, on account of contamination by campers, etc.

Cost of plant, 400 M. G. D. capacity	$6,000,000	
Operating filters—125 days, at $4 per M. G., gives annual cost of $200,000. This capitalized at 4½ per cent	4,450,000	
Filtration cost chargeable to project if filtration is required		$10,450,000

Eleanor-Cherry-Stanislaus-Mokelumne project.

For 215 M. G. D. from watershed which may be made tributary to Lake Eleanor, with tunnels in Coast Range of 400 M. G. D. capacity:	
Tunnels, pipe lines, etc., from San Francisco to western end of San Joaquin Valley pipe line, including branch aqueduct to Lake Chabot as per Hetch Hetchy project (240 M. G. D. supply)	$22,005,000
Pipe line across San Joaquin Valley—maps indicate slightly shorter line than for the Hetch Hetchy Aqueduct, but same cost assumed	8,437,100

[1] These figures are not given in Mr. Freeman's estimates and may be somewhat greater than he would give, as a greater storage for periods worse than 1896–1901 is allowed for than he considers necessary.
[2] Equals A.
[3] Equals B.
[4] Equals C.

Eleanor-Cherry-Stanislaus-Mokelumne project—Continued.

For 215 M. G. D.—Continued.		
Tunnels on Eleanor-Cherry Line—		
9.5 feet diameter, 97,680 feet, at $53		$5,177,000
8 feet diameter, 190,080 feet, at $31.50		5,987,500
8 feet diameter, 37,700 feet, at $40		1,508,000
Siphons across Stanislaus and other streams		150,000
Reservoirs—		
Lake Eleanor Dam, 245 feet high		6,400,000
Cherry Valley Dam, 150 feet high		2,400,000
6 smaller dams on Upper Cherry Creek		1,200,000
Diverting dams and canals on Cherry, Falls, and Rancheria Creeks		300,000
Construction road (assumed same as for Hetch Hetchy)		1,288,100
Water rights on Eleanor-Cherry Creeks		1,070,000
Total for 215 M. G. D		55,922,700
For 185 M. G. D. (57 from Stanislaus, 128 from Mokelumne) additional:		
Duplicate pipe line across San Francisco Bay		2,756,200
Duplicate pipe line across Alameda Creek		131,000
Duplicate pipe line on Lake Chabot Aqueduct		359,400
Extension of Lake Chabot Reservoir		3,211,000
Duplicate pipe line across San Joaquin Valley		8,437,100
Gravity conduit from Stanislaus-Cherry Junction to Stanislaus power house (57 M. G. D. capacity), including tunnels, siphons, fluming, etc., 79,200 linear feet, at $10		792,000
Canal from Stanislaus power house to Sand Bar Flat (460 second-feet capacity), 84,480 linear feet, at $10		844,800
Dam and canal headworks at Sand Bar Flat and at Stanislaus power house		500,000
Reservoirs on Stanislaus watershed—		
Dams at Relief Valley, Kennedys Meadows, Donnels Flat, Kennedys Lake, and Lower Kennedys Meadows		6,660,000
Roads		740,000
Assumed cost of water rights on Stanislaus		2,000,000
Tunnels on Mokelumne line—		
8-foot diameter, 84,480 feet, at $31.50		2,661,000
Siphons on tunnel line		300,000
Gravity conduit (128 M. G. D. capacity), 100,320 feet, at $15		1,504,800
Canal (100 M. G. D.) from North to Middle Forks, 84,480 feet, at $8		675,800
Diverting dam, Middle Fork		50,000
Reservoirs on Mokelumne watershed—		
Dam at Rail Road Flat, 325 feet high		3,364,000
Dam at North Fork and Blue Creek, 325 feet high		4,704,000
Dam at North Branch of Middle Fork, 110 feet high		333,000
Roads		300,000
Assumed cost of water rights		3,000,000
Grand total for 400 M. G. D		99,246,800
First installation, 160 M. G. D. capacity, all required by 1947:		
Cost for 215 M. G. D	$55,922,700	
Less tunnels above Lake Eleanor $1,508,400		
Less portions of Cherry Creek Reservoirs 2,800,000		
Less diversion dams and canals from Falls and Rancheria Creeks 200,000		
	4,508,000	
	51,414,700	
Add for water rights on Stanislaus and Mokelumne Rivers	5,000,000	
	[1]	56,414,700
Time of construction 1914–1920: mean date 1917.		

[1] Equals A.

Eleanor-Cherry-Stanislaus-Mokelumne project—Continued.

Second installation, increasing supply to 272 M. G. D., all required by 1947	[1] $28,939,500
Time of construction, 1943–1947: mean date 1945.	
Third installation, increasing supply to 400 M. G. D., all required by 2000	[2] 13,892,600
	99,246,800
Time of construction, 1973-1977: mean date 1975.	
Time between first and second installations, 28 years.	
Time between second and third installations, 30 years.	
Amount (S), which, if invested at 4½ per cent (r) compound interest in 1914, will finance the project:	
$S=\frac{A}{(1+r)}3+\frac{B}{(1+r)}31+\frac{C}{(1+r)}61=$ [3] $57,700,000.	
Power development:	
95,000 horsepower may be developed from the 215 M. G. D. from Eleanor-Cherry and from the 128 M. G. D. from the Mokelumne at plants on aqueduct line—estimated cost of these at	5,000,000
Value of power at the plants, $20 per horsepower year, or a total of $1,900,000 per year, capitalized at 4½ per cent	42,250,000
Net credit to cost of project	37,250,000

NOTE.—See note as to credit for power under Hetch Hetchy project.

American-Cosumnes-Stanislaus-Mokelumne project.

For 215 M. G. D.: Same as for Eleanor-Cherry-Stanislaus-Mokelumne project, from San Francisco and Oakland, and east end of San Joaquin Valley Pipe Line	$30,442,100
Tunnels on American-Cosumnes Line—	
10.3 feet diameter, 63,360 feet, at $53	3,358,100
8.3 feet diameter, 105,600 feet, at $32	3,379,200
Siphons, Mokelumne, and other streams,	500,000
Concrete gravity conduit (215 M. G. D. capacity), 158,400 feet, at $20 (including short tunnels, siphons, etc)	3,168,000
American Canal (250 M. G. D. capacity), 89,760 feet, at $10	897,600
Pacific house tunnel, 2,100 feet, at $40	84,000
Diverting dams on Sly Park and Camp Creeks	100,000
Reservoirs—	
Dams at Silver Lake	910,290
Dams at Twin Lakes	650,775
Dams at Audrain Lakes	83,522
Dams at Echo Lakes	48,162
Dams at Medley Lakes	138,000
Dams at Alder Creek	347,625
Dams at Slippery Ford, 246 feet high	4,160,000
Dams at Sly Park	339,076
Water rights assumed	4,000,000
Total for 215 M. G. D.	52,606,450
For 185 M. G. D. (128 from Mokelumne, 57 from Stanislaus) additional:	
Duplication of pipe lines and an extension of Lake Chabot reservoir, as per Eleanor-Cherry-Stanislaus-Mokelumne project	14,894,700
Tunnels on Mokelumne line, 8 feet diameter, 21,120 feet, at $31.50	665,250
Conduits, ditches, dams, water rights, etc., on the Mokelumne, as per the Eleanor-Cherry-Stanislaus-Mokelumne project	13,931,600
Tunnels on Stanislaus line, 8 feet diameter, 97,680 feet, at $31.50	3,076,900
Conduits, ditches, dams, water rights, etc., on the Stanislaus, as per the Eleanor-Cherry-Stanislaus-Mokelumne project	11,536,800
Grand total for 400 M. G. D.	96,711,700

[1] Equals B.
[2] Equals C.
[3] By dividing the second installation into two, i. e., adding 55 M. G. D. from Eleanor-Cherry watershed by 1947 and 57 M. G. D from the Stanislaus by 1963, this amount ($57,700,000) would be reduced to $54,600,000.

American-Cosumnes-Stanislus-Mokelumne project—Continued.

For 185 M. G. D.—Coutinued.		
Dates for construction same as for Eleanor-Cherry-Stanislaus-Mokelumne project—		
A=$52,606,450		
B= 32,508,400		
C= 11,596,850		
96,711,700		
Amount which if invested in 1914 at 4½ per cent compound interest will finance project=S=$55,300,000.		
Power development—		
62,000 horsepower (net) may be developed from the 215 M. G. D. on American-Cosumnes and the 128 M. G. D. from the Mokelumne at plants on the Aqueduct line, requiring installation of power houses and machinery only.		
Estimating cost of these at	$3,300,000	
Value of power at the plants $20 per horsepower year, or a total value of $1,240,000 per year, capitalized at 4½ per cent	27,600,000	
Net credit to cost of project		$24,300,000

Mount Shasta Aqueduct (McCloud River project).

For 260 M. G. D.:		
Tunnels (400 M. G. D. capacity).		
12.5 by 13, gravity section.		
424,000 feet, at $66.50		$28,196,000
12.8 diameter, pressure.		
400 feet under Pitt River, at $100	$40,000	
600-foot shafts, at $125	75,000	
		115,000
5,300 feet under Casquinez Straits, at $200	1,060,000	
600-foot shafts, at $150	90,000	
		1,150,000
30,120 feet between Pinole and San Pablo Reservoirs, at $70		2,108,000
Concrete cut and cover, gravity conduit (400 M. G. D.), 538,340 linear feet, at $25		13,458,500
Reenforced concrete flume, 16,200 linear feet, at $35		567,000
Reenforced concrete pressure pipe—		
10-foot diameter, 38,800 feet, at $32.50		1,261,000
8.5-foot diameter, 15,840 feet, at $30		475,200
Steel pipe (cement lined and coated)—		
10-foot diameter; shell from ¼ inch to ⅜ inch; price per foot from $30 to $53.50, 20,400 linear feet		760,750
8.75-foot diameter; shell from ¼ inch to ⅜ inch, price per foot from $30 to $40, 2,000 linear feet		71,250
6.75-foot diameter; shell from ¼ inch to 7/16 inch, price per foot from $15.50 to $22.50, 44,800 linear feet		849,600
Submerged pipe San Francisco Bay, 6.75 feet diameter (pressure about 150 feet less than for Hetch Hetchy pipes at Dumbarton Point), 18,480 linear feet at $100		1,848,000
Bridge for siphon at Sacramento River crossing		120,000
Bridge for siphon at Putah Creek		15,000
Diverting dam at intake, McCloud River, 85,000 cubic yards, at $8		680,000
Reservoirs, San Pablo and Pinole Creek—		
2,500 acres, land at $150		375,000
Construction of dams		2,500,000
Water rights		2,000,000
Purchase of watershed (exclusive of stumpage), 400,000 acres, at $7.50		3,000,000
Total for 260 M. G. D. supply		59,550,300
For 140 M. G. D. additional:		
Duplication of pipe lines including pipe under San Francisco Bay		5,265,800
Bridges for siphon at Sacramento River and Putah Creek		135,000
Grand total for 400 M. G. D.		64,951,100

NOTE.—The board of engineers has increased this estimate of cost 10 per cent.

Mount Shasta Aqueduct, alternate project for bay crossing.

For 260 M. G. D.:	
From cost of first installation as above	$59,550,300
Deduct submerged pipe crossing of San Francisco Bay	1,848,000
	57,702,300
Add as an approximate equivalent of 60 miles of pipe of progressively decreasing capacity—	
40 miles or 211,200 linear feet of 6.75-foot of pipe, at $16	3,379,200
Submerged pipe at Dumbarton Point, 4,880 feet, at $90	439,200
Capitalized cost of pumping, at 4½ per cent, to restore 160 feet of head lost by friction in increased length of pipe, an average of 100 M. G. D. during period first installation is used	4,000,000
Total for 260 M. G. D. supply	65,520,700
For 140 M. G. D. additional:	
From cost of complete original project	64,951,100
Deduct two lines of submerged pipe under San Francisco Bay	3,696,000
	61,255,100
Add duplicate lines of 6.75-foot pipe, 40 miles	6,758,400
Add duplicate submerged pipes at Dumbarton	878,400
Capitalized cost of pumping 200 M. G. D	8,000,000
Total for 400 M. G. D. supply	76,891,900

NOTE.—The board of engineers has increased the estimate of cost 10 per cent.

First installation 260 M. G. D. capacity, all needed by 1974	[1] $59,550,300
Time of constructing, 1914–1920; mean date, 1917.	
Second installation, increasing capacity to 400 M. G. D., all required by A. D. 2000	[2] 5,400,800
Time of constructing, 1972–1974; mean date, 1973.	
	64,951,100

Time between first and second installation, 56 years.

Amount (S) which if invested in 1914 at 4½ per cent (r) compound interest, will finance the project.

$$S=\frac{A}{(1+r)^{8}}+\frac{B}{(1+r)^{60}}=\$52,500,000.$$

For alternate scheme avoiding long bay crossing:	
A	$65,520,700
B	11,371,200
	76,891,900
S	58,100,000

Filtered supply from Sacramento River.

For 133⅓ M. G. D.:	
Filtration plant and pumps based on estimates of Allen Hazen for a 60 M. G. D. plant with 15 per cent added for contingencies—	
Intake and pumping station at Rio Vista, $245,000$\times\frac{133\frac{1}{3}}{60}\times 1.15$	$626,000
Intake, filters, coagulating basins, pure-water reservoirs, and pumping station at Antioch, $2,730,000$\times\frac{133\frac{1}{3}}{60}\times 1.15$	6,980,000
Distributing reservoir, Oakland, not increased	1,170,000
Lands for right of way and various plants	625,000
Tunnels 12.8 diameter (400 M. G. D. capacity), 63,360 linear feet at $68	4,308,500

[1] Minus A. [2] Minus B.

Filtered supply from Sacramento River—Continued.

For 133⅓ M. G. D.—Continued.	
Steel pipe (cement lined and coated), 7.75 feet diameter; shell from ¼ inch to $\frac{9}{16}$ inch, and price per foot varying from $17.23 to $29.70, 143,600 linear feet	$2,884,900
Extra work on Sacramento and San Joaquin River crossings and on peat lands, Sherman Island	500,000
6.75 feet diameter, shell from ¼ to ⅜ inch, price per foot varying from $15.50 to $19.50, 48,000 linear feet	885,500
Submerged pipe under San Francisco Bay (6.75 feet diameter), $\frac{7}{16}$-inch shell, 17,900 feet, at $95	1,700,000
Total construction cost for 133⅓ M. G. D. plant	19,679,900
Operating cost of filters, pumps, etc., 133⅓ M. G. D. for 365 days at $17 per M. G.=$827,300, this capitalized at 4½ per cent	18,350,000
Total for 133⅓ M. G. D. with one-half delivered at elevation 140 feet in San Francisco	38,029,900
Capitalized cost of raising this portion to 200 feet head	1,375,000
Total for 133⅓ M. G. D. to compare with other projects	39,404,900
For second installation of 133⅓ M. G. D.:	
Pumps, filters, coagulating basins, reservoirs, etc., as per first installation	9,401,000
7.75-foot diameter steel pipe, second line	3,384,900
6.75-foot diameter steel pipe, second line	2,585,500
Capitalization of operating, cost of pumps and filters as per first installation	18,350,000
Cost of pumping one-half supply in San Francisco from 140-foot to 200-foot head, capitalized	1,375,000
Total cost for 266⅔ M. G. D.	74,501,300
For third installation of 133⅓ M. G. D.:	
Pumps, filters, etc., as above	9,401,000
7.75-foot diameter steel pipe, third line	3,384,900
Capitalization of operating, cost of pumps, filters, etc., as per previous installations	18,350,000
Cost of pumping one-half supply on San Francisco side of bay from 140-foot to 200-foot head, capitalized	1,375,000
Grand total for 400 M. G. D.	107,012,200
Alternate project for bay crossing:	
Additional cost would be substantially the same as for the Mount Shasta Aqueduct alternate scheme	15,636,800
Making total with Dumbarton Point crossing	122,649,000
First installation, 133⅓ M. G. D. capacity, all required by 1937 [1]	39,404,900
Time of constructing, 1914–1918; mean date, 1916.	
Second installation, increasing capacity to 266⅔ M. G. D., required by 1976 [2]	35,096,400
Time of constructing, 1935–1937; mean date, 1936.	
Final installation, increasing capacity to 400 M. G. D., all required by A. D. 2000 [3]	32,510,900
Time of constructing, 1974–1976; mean date, 1975.	
	107,012,200

Time between first and second installations, 20 years.
Time between second and third installations, 39 years.
Amount (S) which if invested in 1914 at 4½ per cent=(r) compound interest will finance the project—

$$S=\frac{A}{(1+r)^2}+\frac{B}{(1+r)^{22}}+\frac{C}{(1+r)^{61}}=\$51,700,000.$$

[1] Equals A. [2] Equals B. [3] Equals C.

Filtered supply from Sacramento River—Continued.

For alternate scheme for avoiding long bay crossing:	
A	$43,385,200
B	39,076,700
C	36,491,100
	118,953,000
S	57,040,000

Yuba River project.

For 164 M. G. D., total supply delivered to San Francisco Aqueduct below intake at Bourn power house near Bridgeport:	
Tunnels—	
9 feet diameter for gravity and light pressure, 338,900 linear feet, at $42.50	$14,400,000
Crossing of Carquinez Straits, 5,300 feet, tunnel and shafts	1,150,000
Concrete, cut and cover, gravity conduit, 125,000 linear feet, at $20	2,500,000
Reenforced concrete flume, 2,200 linear feet, at $30	66,000
Steel pipe, 6.75 feet diameter (cement lined and coated), shell from ¼ inch to 1 inch thick; price per foot, from $15.50 to $40; double line, each 314,020 feet long	19,382,000
Submerged pipe, 6.75 feet diameter—	
Double line under San Francisco Bay, each 18,480 feet long	3,696,000
Double line under Sacramento River	300,000
Double line under Feather River	700,000
Bridges for siphons (double lines)—	
Putah Creek	30,000
North Fork Yuba River	80,000
Works above intake at Bourn power plant—	
Closed gravity conduits—	
95,000 feet (114 M. G. D. capacity) from Bourn power house to Columbia Hill reservoir at $15	1,425,000
31,700 (50 M. G. D.) from Bourn power house to Sweetland reservoir, at $10	317,000
Open canals with short tunnels, protected from local drainage—	
90,000 feet (400 M. G. D. capacity) on South Yuba above Columbia Hill reservoir, at $20	1,800,000
84,500 feet (500 M. G. D. capacity) on Middle Yuba above Sweetland reservoir, at $22	1,860,000
50,125 feet (95 M. G. D. capacity) from Starr power house to Bowman Lake, at $8	401,000
Tunnel from Jackson Creek to English reservoir on Middle Yuba drainage, 10,500 feet, at $35	367,000
Diverting dams—	
Middle Yuba below English reservoir	50,000
Middle Yuba (with canal headworks) near Bloody Run	100,000
South Yuba (with canal headworks) above Washington	100,000
Reservoirs—	
English reservoir, three dams, 81 feet high; Bowman Lake Dam, 150 feet high; Faucherie Lake Dam, 44 feet high; French Lake Dam, 90 feet high; Sawmill Flat Dam; Chain of South Lakes Dam; Shotgun Lake Dam, 35 feet; Malakoff Reservoir Dam; Columbia Hill Dam; Shady Creek Dam, 180 feet; Sweetland Dam, 230 feet	[1] 7,220,000
San Pablo Creek Reservoir	2,000,000
Water rights (assumed)	4,000,000
Grand total	61,944,000

[1] This amount can be considered as but little better than a guess. In many of the lakes there are dams, more or less substantial. The last four in the list of reservoirs covered by this estimated amount require very large dams. Conditions are very uncertain.

Yuba River project—Continued.

For 164 M. G. D.—Continued.
Works above intake at Bourn power plant—Continued.
Power development—
Power can be developed from a much greater quantity of water than can be diverted to San Francisco. Assuming that power developed from the water diverted (164 M. G. D.) belongs with the project, there will be 54,600 H. P. (net). Estimating cost of power installation at $3,000,000; value of power at the plants at $20 per horsepower year, or total value of $1,092,000 per year. Capitalized at 4½ per cent..... $24,300,000

Net credit to cost of project..... $21,300,000

Summary of estimates.

Project.	Total capacities and construction costs for successive installations.						Present (1914) value of amounts required for financing projects, 4½ per cent compound interest.
	M.G.D.	Cost.	M.G.D.	Cost.	M.G.D.	Cost.	
Hetch Hetchy, including Eleanor-Cherry.....	160	$37,501,400	240	$51,412,200	400	$77,367,400	$38,900,000
Eleanor-Cherry, Stanislaus-Mokelumne.....	160	56,414,700	272	85,354,200	400	99,246,800	57,700,000
American, Cosumne-Stanislaus, Mokelumne.....	160	52,606,450	272	85,114,850	400	96,711,700	55,300,000
McCloud (bay crossing).....	260	59,550,300	400	64,951,100	.....	.....	52,500,000
McCloud (alternate line) via Dumbarton Point.....	260	65,520,700	400	76,891,900	.....	.....	58,100,000
Sacramento filtered supply (bay crossing).....	133⅓	39,404,900	266⅔	74,501,300	400	107,012,200	51,700,000
Sacramento (alternate line) via Dumbarton Point.....	133⅓	43,385,200	266⅔	82,461,900	400	118,953,000	57,040,000
Yuba River (bay crossing)...	164	61,944,000	.....	.....	.....	.....	.....

For power valuations—see under detailed estimates for each project.
NOTE.—The board of engineers has made modifications in this table as to McCloud River.

CONCLUSIONS.

First. In addition to the greatest economic development of local sources of water supply, there may be needed for a metropolitan district comprising San Francisco and the bay cities by the end of the twentieth century 400 M. G. D.

Second. With the possible development of reservoir capacity on the watershed of the Tuolumne, the waters of that river are sufficient for the reasonably prospective needs of the metropolitan district and of the Turlock and Modesto irrigation districts and adjacent areas which will be dependent on that river for its supply, if the Hetch Hetchy Valley's capacity is included, but not without it. Irrigation needs, as distinct from Turlock and Modesto rights, as described herein, can probably not be provided for without the use of some of the reservoir sites on the Eleanor-Cherry-Hetch Hetchy watershed. This need not, however, conflict with the city's use of reservoirs for a 400 M. G. D. supply.

Third. The Lake Eleanor and Cherry Creek Basins may be developed to yield a dependable supply of 190 M. G. D. This yield may

be increased to 225 and to 255 M. G. D. by diverting water from Falls and Rancheria Creeks to Lake Eleanor, but at the expense of destroying some of the beauties of the Hetch Hetchy Valley.

Fourth. Supplies of water in varying quantities may be obtained from other watersheds, as shown by the table on page 125 and more in detail on preceding pages.

Fifth. None of the other catchment areas can be under quite so efficient regulation as to sanitary conditions as are those on the Tuolumne under the park regulations, without greatly increased expense of acquiring title to the lands.

Sixth. Neglecting the value of practicable power development along lines of aqueducts, the present worth of the cost of complete development up to 400 M. G. D. is nearly $13,000,000 less for the Hetch Hetchy project than for any other, though the total actual cost of construction, regardless of the lapse of time before such construction would be needed, is $12,500,000 greater than for the one involving the least actual cost for construction. The additional cost of carrying conduits from Oakland to San Francisco via Dumbarton Point over the cost of the more direct bay crossing is between $5,000,000 and $6,000,000.

Seventh. Taking into account the value of power development, the difference in favor of the Hetch Hetchy project is much greater than stated above.

Supplemental Report.

In accordance with the request of the Secretary of the Interior that estimates of cost of developing certain sources of water supply be prepared by the engineers of the city of San Francisco and of the Spring Valley Water Co., using so far as practicable the same unit costs that had been used by Mr. Freeman for the Hetch Hetchy project, there have been received reports and estimates as follows:

Cost estimate on the McCloud River project by M. M. O'Shaughnessy, city engineer of San Francisco.

Report on comparative cost estimates for several sources of supply as alternatives to the Hetch Hetchy project, by John R. Freeman, consulting engineer to San Francisco.

Estimate of cost of constructing the Hetch Hetchy dam to a height of 200 feet, so that the excess capacity may be used for irrigation, by M. M. O'Shaughnessy, city engineer.

Estimates of cost for further development of the Spring Valley Water Co.'s resources by F. C. Hermann and by Herman Schussler, chief and consulting engineer, respectively, of the Spring Valley Water Co.

Estimate of cost for a supply from the Yuba River by G. A. Elliott, superintendent of operation and maintenance of the Spring Valley Water Co.

In addition to the reports and estimates just mentioned, there have been received since the November hearing at Washington:

An estimate of cost of Mount Diablo Range tunnels, according to the Freeman plan for the Hetch Hetchy Aqueduct, by William Mulholland and J. B. Lippincott, chief and assistant chief engineer, respectively, of the Los Angeles Aqueduct.

An estimate of cost for a supply from the McCloud River, by Rudolph W. Van Norden, consulting engineer to the Mount Shasta Aqueduct Corporation.

A general statement and discussion of the water-supply situation, by Luther Waggoner, consulting engineer to the Turlock and Modesto irrigation district.

A copy of a letter from J. C. Shinn to Supervisor Koshland on the question of taking further water from the ground-water sources of the Spring Valley Water Co. on the east side of the bay.

A communication from Francis Burton Harrison, M. C., Sixteenth New York district, suggesting the Merced River in connection with the Tuolumne as a source of water supply.

A paper by F. C. Hermann, showing that standard methods, used by J. R. Freeman elsewhere were used by Spring Valley Co.'s engineers in estimating yield of Alameda Creek.

SPRING VALLEY WATER CO.'S ESTIMATES.

The estimates prepared by Mr. Schussler and by Mr. Hermann are for the development of 160 M. G. D. and 170 M. G. D., respectively, from resources of Spring Valley Water Co., in addition to the quantity now supplied.

An additional supply of 160 M. G. D. is about 50 M. G. D. greater than I have estimated as the practicable limit of development and about 80 M. G. D. greater than has seemed to me an economically practicable limit, considering local needs of water on the watersheds from which it is proposed to divert them.

Mr. Hermann's cost estimate is $18,500,000 and Mr. Schussler's is $21,906,700, as against Mr. Freeman's estimate of $36,981,000, for Hetch Hetchy development up to the point of a safe supply, through dryest years, of 160 M. G. D. The Spring Valley supply could be developed in several installments, extending over several years, thus saving considerable amounts in interest on construction costs over those required for the Hetch Hetchy supply developed to the capacity stated, but the latter would then have all tunnels of 400 M. G. D. capacity, and these comprise a large portion of the aqueduct, so that to increase the supply to the larger quantity requires principally the duplication of steel pipe lines and the increase of storage capacity.

For augmenting the Spring Valley Water Co.'s supply beyond the limits estimated upon by Messrs. Schussler and Hermann, as briefly reviewed above, estimates of cost of a supply from the Yuba River by G. A. Elliott have been submitted. The project for development is substantially that proposed by Samuel Storrow and W. W. Waggoner described on pages 89–91. His estimate of cost is based on a supply of 200 M. G. D., though the reservoir capacity given is considerably less than that which I have shown is necessary for a supply of 164 M. G. D. during dryest periods.

The estimated cost including power houses and transmission lines for power to pumping plants is $35,156,989. Included in this amount is cost of construction of reservoirs, $3,713,932, instead of over $7,000,000, taken by me for this item. The smaller estimated cost is due partly to the smaller storage capacity provided, and partly to the much smaller unit costs for the Sweetland and Shady Creek reservoirs, where the recovery of gold from material sluiced into the dams by hydraulic process is counted on to reduce the cost.

To the $35,156,989, construction cost, Mr. Elliott adds for capitalized cost of pumping against a head of 625 feet after crossing Suisun Bay, $3,067,471. This is based on an operation and maintenance cost per kilowatt hour of less than one-twentieth of a cent, it being stated that "the annual charge for pumping is exclusive of fixed charges, which will of course be taken care of with the fixed charges of the remainder of the project." It is not at all clear that the allowances which have been made for fixed charges, including depreciation, in the project as a whole are sufficient to cover depreciation on the power and pumping plants. In the estimates of cost made

by Mr. Hermann, the cost of power for pumping is taken at six-tenths cent per kilowatt hour.

Leaving the other items of the estimate as made by Mr. Elliott, in my opinion, the total should be not less than $48,000,000, instead of $38,224,600.

Compare with this my estimate of cost of a gravity supply of 164 M. G. D. from the Yuba River, $61,944,000, with a large credit due to power that might be developed from the water diverted from the river.

COMBINATION OF SIERRA SUPPLIES AS ALTERNATIVE TO THE HETCH HETCHY PROJECT.

Mr. Freeman's supplementary report dated December 23, 1912, makes estimates of cost for supplies from the Eleanor-Cherry catchment area and the streams to the north as follows:

165 M. G. D. from Eleanor-Cherry Creek		$42,389,000
60 M. G. D. from Stanislaus	$17,340,000	
Capitalized cost of filtering	3,900,000	
		21,240,000
60 M. G. D. from Mokelumne		35,453,988
285 M. G. D.		99,082,988

For a further increase Mr. Freeman states that recourse would have to be had to the American-Cosumnes watershed, for the cost of which he quotes Mr. Dockweiler's estimate of $69,210,000 for a supply of 220 M. G. D.

Mr. Freeman's project for combining these sources does not count on so full a development of the Eleanor-Cherry watershed and areas that may be made tributary to it as does that estimated upon by me in preceding report. Neither does it bring the aqueducts from the several sources to a common point until the Tesla Portal on west side of San Joaquin Valley is reached.

This estimate of cost for a supply of 285 M. G. D. differs but little from that for either of the two combinations totaling 400 M. G. D. made by me. (See pages 131–134 and page 138.)

SACRAMENTO RIVER FILTERED SUPPLY.

Mr. Freeman's estimates for a Sacramento River supply are for successive stages of 145, 275, and 400 M. G. D., the San Francisco portions of which are carried across San Francisco Bay at Dumbarton Point. The costs, so far as carried out, are less than those given in the estimates on page 136 and page 138.

A supply from the Sacramento River can much more feasibly be developed in smaller units, with consequent saving in interest charges, than have been estimated upon by me, or than is practicable for a distant mountain supply.

In the communication from Luther Waggoner, consulting engineer for Turlock and Modesto irrigation district mentioned above, he strongly advocates the Sacramento River as a source of supply, with filtration works, and the development of the Eleanor-Cherry supply for power production, the power to be used for the necessary pumping of the Sacramento supply; the stored water to be available for irrigation uses.

M'CLOUD RIVER SUPPLY.

Since the hearing at Washington in November there have been submitted to the board several estimates of cost for a supply from the McCloud River as follows:

By R. W. Van Norden, for Mount Shasta Aqueduct (corporation), $54,624,562.

This estimate takes the main supply for San Francisco across the bay from Oakland, but provides an extra pipe line of 50 M. G. D. capacity along east side of bay to a connection with Spring Valley Water Co.'s pipes at Dumbarton Point.

By Horace Ropes (assistant engineer to Mr. Freeman):

First stage	$55,477,000
Second stage	16,858,000
Total	72,335,000

This estimate is for pipe line crossing the bay at Dumbarton Point, but does not include capitalization of cost of pumping to make up loss head, due to extra length of conduit, necessary to make use of this more favorable crossing.

By M. M. O'Shaughnessy, city engineer:

Scheme A.—Stated to be substantially the project submitted by Mount Shasta Aqueduct Corporation, cost for 200 M. G. D. supply, $81,073,700.

The criticisms of this scheme are, in my opinion, not well founded, as delivery on either side of the bay would be at elevations not lower than would be the case from the Hetch Hetchy. The criticism as to length of aqueduct being underestimated may be true to some extent. In estimate made by me, pages 134–135 and page 138, this, as well as the possibility that a considerable portion of the aqueduct estimated as cut and cover conduit may have to be either in tunnel or of flume construction, has been allowed for by the large unit price for this portion of the work.

Scheme B.—Stated to be much more nearly comparative with the Hetch Hetchy scheme.

Cost for 200 M. G. D. supply	$91,739,875
Additional cost for increase to 400 M. G. D.	9,999,157
Total	101,739,032

By this scheme the water would be diverted from the McCloud River at a point about 15 miles further upstream and at an elevation about 300 feet higher than by Scheme A. It delivers water for Oakland at Lake Chabot. The aqueduct then runs south to Irvington, from which point to San Francisco it follows the location proposed for the Hetch Hetchy Aqueduct.

FEATHER RIVER AND INDIAN VALLEY.

In the discussion at the hearing before the Secretary of the Interior it was suggested that the utilization of Indian Valley as a reservoir would overcome the objections to the Feather River as a source of supply.

Such use would not overcome the necessity for filtration unless the conduit were extended from the points of intake suggested in connection with a supply from this river, as described on page 87, a distance of about 48 miles through the rugged Feather River Canyon country to the proposed reservoir. The total length would then be nearly as great as that from the McCloud River, and very much more expensive.

Indian Valley is one of the reservoir sites referred to on page 87 in connection with the regulation of the flow of the Sacramento River when drafts for irrigation injuriously affect the low-water discharge and navigation interests. On pages 128 and 129 it was shown that this reservoir site ranks very high in economy of storage.

It is a very beautiful valley, largely devoted to dairying interests, and contains three small towns, two of which would be flooded, and

the third would have most of its business destroyed by the conversion of the valley into a reservoir.

In connection with a report to the California Débris Commission made by me in 1910 on the control of floods in the Sacramento Valley the cost of a reservoir at Indian Valley was estimated as follows:

Land, 12,600 acres, at $50		$630,000
Buildings in towns of Crescent Mills and Taylorsville and on ranches, and capitalization of incomes from destroyed business		630,000
Mining property		100,000
Dam:		
28,000 cubic yards excavation, at 75 cents	$21,000	
105,600 cubic yards concrete, at $9.50	1,003,200	
		1,024,200
Total		2,384,200

This estimate is for a reservoir of 600,000 acre-feet (196,000 M. G.) capacity; dam 120 feet high above low-water surface of creek at dam site.

THE SAN FRANCISCO BAY CROSSING.

So much stress has been laid on the hazard and expense of crossing the wide portion of San Francisco Bay westerly from Oakland by the engineers for San Francisco, that they were instructed by the Secretary of the Interior to make estimates of cost for alternative routes crossing the bay at Dumbarton Point (where the proposed Hetch Hetchy Aqueduct crosses), for conduit lines from sources which would more directly and naturally cross at Oakland.

In the reports dated December 23, 1912, Mr. Freeman's estimate of cost for a Sacramento River supply and Mr. O'Shaughnessy's estimate for a supply of 200 M. G. D., and subsequent enlargement to 400 M. G. D from the McCloud River are for the route via Dumbarton Point only.

In my estimates for pipe lines for the long crossing, I have used the same cost per foot (for same size pipe) as for the Dumbarton Point crossing on the assumption that the much greater service to be obtained from the plant required for placing submarine pipe would easily compensate for the greater difficulties encountered.

In talking with other engineers about conduits crossing the bay, my previous opinion as to the feasibility of the long crossing and lack of great hazard has been confirmed. A single pipe line of, say, 50 M. G. D. capacity, down the east side of the bay to a connection with the Spring Valley Water Co.'s mains, as is proposed and estimated upon by Mr. Van Norden in connection with the McCloud River project, together with the large storage capacity of the Peninsular reservoirs, should afford sufficient supply during the time required to make repairs to the conduit if a break should occur.

The following letter from Mr. W. A. Cattell, member and director of American Society of Civil Engineers and member of American Society of Mechanical Engineers, whose experience peculiarly fits him to pass judgment on this proposition, is quite to the point. Among his engagements in connection with large works was that of preparing estimates for bids for contractors for the New York-Brooklyn Subway, including the tunnel section under the East River.

SAN FRANCISCO, CAL., *January 11, 1913.*

Mr. H. H. WADSWORTH,
United States Assistant Engineer, San Francisco, Cal.

MY DEAR MR. WADSWORTH: Confirming our recent conversation relative to the practicability and cost of constructing and maintaining a pipe line across the Bay of San Francisco of sufficient capacity to supply the city of San Francisco with water, I would say that in 1911 I had occasion to investigate the feasibility of constructing a traffic tunnel under the bay from Oakland to San Francisco.

This investigation was undertaken in association with Mr. Taggert Aston, civil engineer, of this city, at the request of Sir Douglas Fox, the eminent English engineer. I am inclosing herewith for your information a copy of a brief report I made on the project under date of July 5, 1911. For reasons which you will readily appreciate, this report is not for publication; it is for your personal use only. While it deals more particularly with the cost, traffic, and earnings than the engineering features involved, it is, as you will observe, predicated upon the entire feasibility of the project from the engineering standpoint. You will further note in the report that one of the sources of anticipated revenue was the rental of space in the tunnel for the water-supply mains.

While the engineering features of the project were not described in this report, they were elaborated in considerable detail before the estimates given in the report were made.

The tunnel was projected to start from a point in Oakland to which all the through and local transportation lines could be converged, and to pass thence in a direct line under the S. P. Mole to the foot of Mission Street, San Francisco, thence up Mission Street to a union terminal at Twelfth Street. The total length of the line would be approximately 6¼ miles, as follows:

7,200 linear feet double-track cut and cover work.
14,500 linear feet subaqueous double-tube tunnel.
4,500 linear feet double-track tunnel in rock and hardpan.
6,700 linear feet double-track open cut.

The greatest depth of water which occurs near the San Francisco shore line is 78 feet at low water.

No borings or other data relative to the material to be encountered were available, other than those shown on the United States Coast and Geodetic Survey chart, but assuming the material to be the worst possible to handle and basing costs on the actual costs of the Pennsylvania Railroad tunnels in New York, the total cost of the 6¼ miles, exclusive of terminals and equipment, would not exceed $20,000,000, including a liberal allowance for contingencies. This estimate is for a double-track structure identical in size with the P. R. R. tunnels in New York, and therefore capable of handling standard railroad equipment. In the design of such a structure, provision could be made, at small additional cost, for water-supply mains, with a capacity of 200,000,000, or more, gallons daily.

The actual construction of such a tunnel may, of course, be a remote possibility. When I first took the matter up I was inclined to the belief that it would be many years before the population and traffic would be sufficient to warrant such an expenditure. A careful study of the problem, however, indicates that the project could be commercially feasible at the present time, if all the through and local transportation systems could be brought to unite in its construction and operation.

Quite independently of the tunnel project, I have given considerable thought to the feasibility of laying water mains across the bay. The laying of such pipes has been contemplated in a number of the projects for supplying San Francisco with water, which have been advocated by some of the ablest engineers from time to time in the past. So far as I am aware no engineer of ability who has carefully studied the situation has found any special difficulty or extreme cost.

Mr. Allen Hazen estimates the cost of laying a 30-inch line at $50 per linear foot. This would seem to be a very liberal allowance, as similar work in other localities has been done for very much less.

The contract price for laying the 60-inch cast-iron pipes for the Boston outfall sewer was $17.33 per linear foot. This work was done in 1903. The maximum depth of water was 53 feet. (See Third Annual Report, Metropolitan Water and Sewerage Board, Jan. 1, 1904.)

I have been in correspondence with a New York contractor of large experience in the laying of subaqueous pipe, as to the feasibility and cost of a pipe line across the bay, and in addition to my own judgment, I have the benefit of his experience in such matters, as applied to the conditions here. From the study I have made of this matter I am abundantly satisfied that it is entirely feasible to lay and maintain such pipe lines, and that the cost will be reasonable.

I can not at this time make a satisfactory estimate of the cost of laying the mains. This can be done with certainty only when the economic diameter and number of pipes is determined, which in turn will be dependent on the capacity required and the head under which the mains will be operated. I am satisfied, however, that the construction of the pipe line across the bay is not only possible but that it will result in a saving of from $4,000,000 to $6,000,000, as against bringing the water around the head of the bay. This extra length of line seems to me to be entirely unnecessary, and further to be fraught with as much or even more danger of interruption of service.

The possible danger from earthquake will doubtless cause some sentimental objection to the construction of either the tunnel or the pipe line under the bay, but I apprehend no danger from this source. There is no evidence of any slip along the old faults underlying San Francisco Bay within historic time; all of the known slips have been along faults to the west, and it is probable that the faults under the bay have long been healed and that any future movements will be along the faults passing through the westerly portion of the city of San Francisco.

Yours, very truly,

W. A. CATTELL.

THE MERCED RIVER IN COMBINATION WITH THE TUOLUMNE AS A SOURCE OF SUPPLY.

A letter addressed by Francis Burton Harrison, M. C., to the Secretary of the Interior states that "An economical and adequate source of water supply for San Francisco consists of one large and three small reservoirs with a combined capacity of 123,000 M. G.," lying between the Merced and Tuolumne Rivers. The four reservoirs are at elevations 200 to 300 feet above sea level and "are so situated that water can be drawn from both the Tuolumne and Merced Rivers."

An investigation of the suggestion made by Congressman Harrison shows that the reservoirs mentioned would be at too low an elevation either for supplying water by gravity or for desirable storage; the latter on account of the very hot summer weather. The large hotel and camping population in Yosemite Valley would make filtration necessary. The Merced River is much less able to supply irrigation needs than is the Tuolumne.

The drainage area above Merced Falls is 1,000 square miles, or two-thirds that of the Tuolumne above La Grange, and the run-off per square mile is from 60 per cent to 80 per cent of that of the Tuolumne. The annual water crop is thus only about one-half that of the Tuolumne.

According to statements made by the Merced Water Users Protective Association, there are 200,000 acres of irrigable lands lying under the Merced River.

A complaint has recently been filed with the State railroad commission against the Crocker-Hoffman Land & Water Co., whose water rights cover the entire flow of the river in excess of 300 second-feet and one-quarter of the flow when it is between 75 and 300 second-feet. The complaint is brought for the purpose of compelling the Crocker-Hoffman Co. to properly reconstruct its works so as to reduce present waste from 45 per cent to a more reasonable one of 25 per cent and to construct a reservoir of 100,000 acre-feet capacity, stating that the company owns sites for reservoirs having capacity of 200,000 acre-feet (65,000 M. G.).

From this showing, together with previous discussions on the Tuolumne River and the irrigation needs of the San Joaquin Valley,

it seems clear that this new suggested supply is insufficient and that the reservoirs mentioned are needed for irrigation purposes.

Careful consideration of the several reports and estimates which have been received since the November hearing, briefly reviewed above, leads to the conclusion that the comparative estimates of cost, as per my report of December, 1912, represent fairly the relative economy of the various sources of water supply considered, and that the conclusions there reached still hold.